THE MARCH SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

THE SCIENCE PRESS

LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.

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Vol. XLIV, No. 3 March, 1937 Whole No. 258

The Scientific Monthly

An Illustrated Magazine Devoted to the Diffusion of Science

J. McKEEN CATTELL, Editor

WARE CATTELL, Associate Editor

Published by THE SCIENCE PRESS

LANCASTER, PA.—NEW YORK, N. Y., Grand Central Terminal—GARRISON, N. Y.

Single Number, 50 cents Yearly Subscription, $5.00

Entered as second-class matter at the post office at Lancaster, Pa., July 18, 1923, under the Act of March 3, 1879

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THE SCIENTIFIC MONTHLY

MARCH, 1937

THE EARTH'S INTERIOR, ITS NATURE AND COMPOSITION

By Dr. LEASON H. ADAMS
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Two events in the last few years have made possible a noteworthy advance in our knowledge of the earth's interior, and have for the first time extended our ideas on this subject definitely beyond those of the early Greek philosophers. The two aids to progress were, first, the precise measurement of the elastic properties of rocks and, second, an improved technique in seismology which permitted the accumulation of reliable data on the speeds of waves from near and from distant earthquakes. Other researches in geophysics have played an important, although secondary rôle, and have promoted a steady improvement in our knowledge of the earth as a whole. It is the object of this communication to summarize briefly the present notions concerning the earth's interior and the steps by which the information has been obtained.

Origin of the Earth

A discussion of the interior of the earth should properly start with a consideration of its origin and its place in the universe. Geophysics begins with cosmogony. Our earth is a spherical body about 8,000 miles in diameter floating in nearly empty space. Its nearest neighbor, the moon, is a quarter of a million miles away. Together, they revolve around the sun at a distance of some 90 million miles. The other planets of the solar system circle around the same sun, which, although by far the largest object in the system, is merely a star like countless others that dot the sky, and is, as stars go, a rather small and insignificant one. Separated from the sun by enormous distances are the other stars of our galaxy, which has a disk-like form and an extent of at least 50,000 light years, and is merely one of the innumerable spiral nebulae scattered irregularly through space at an average distance of perhaps 1,000,000 light years.

On so vast a scale, our earth, a tiny planet accompanying a small star, seems to dwindle into insignificance, but it is after all the place where we dwell and have our being, and for us it has the importance attaching to a great object, which, except for the surface layers, is as yet unexplored.

It is now generally accepted that the earth was created from the parent sun about 2,000 million years ago through tidal disruption by a passing star. The subsequent liquefaction and solidification of the detached mass of glowing gas formed the juvenile earth. This notion, advanced by Jeans and Jeffreys, is quite different from that involved in the nebular hypothesis of Laplace, according to which the sun was originally surrounded by a rarefied nebula which rotated about

the central mass. As the nebular material cooled it was supposed to contract and increase its speed of rotation, until finally the centrifugal force was sufficient to detach a ring of material, which condensed to form a planet. Although accepted for many years, the hypothesis was finally discarded on purely mathematical grounds. The theory now in favor also differs in many important details from another tidal theory, the planetesimal hypothesis enunciated by Chamberlin and Moulton. This was the first to account satisfactorily for many of the major features of the solar system, and involved the formation, from the tidal protuberances, of swarms of solid fragments (planetesimals), which coalesced around various nuclei and thus produced the planets. The significance of the modern theory, for the purposes of this discussion, lies in the supposition that *the earth for a brief time after its creation was entirely molten,* well stirred by convection, and, to the extent that the component substances were miscible in the liquid state, quite homogeneous in composition.

Nature of the Problem

The composition and state of the earth's interior has long remained a problem of great difficulty. It is at the same time a subject of lasting interest, alike for the scientist and for the layman. There is always a certain fascination in the mysterious and unknown, especially when it appears impossible to solve the problems that are presented. If it should seem a hopeless task to learn anything about the interior of the earth, we might profit by adopting that philosophical attitude toward the origin of the earth and the nature of its interior which was expressed by Barrell[1] as follows:

> The history of the earth is read in the rocks which have been thrust up by internal forces and beveled across by erosion. The nearer events are clearly recorded in the sequence and nature of the sedimentary rocks and their fossils. But the oldest formations have been folded, mashed, and crystallized out of all resemblance to their original nature, and intruded by molten masses now solidified into granite and other igneous rocks. Fossils, the time markers of geology, if once existent, have been destroyed, and, as in the dawn of human history, vast periods of time are dimly sensed through the disordered and illegible record. This crystallized and intricately distorted series of the oldest terrestrial rocks tells of an earth surface on which air and water played their parts much as now. But it was a surface repeatedly overwhelmed by outpourings of basaltic lava on a vaster scale than those of later ages, and the crust was recurrently broken up and engulfed in the floods of rising granitic magmas. Here the geologic record begins, but the nature of its beginning points clearly to the existence of a prehistoric eon. At the farther bounds of this unrecorded time, forever hidden from direct observation, lies the origin of the earth.
>
> But the mind of man will not be baffled. Since he may not see directly he will see by inference. Convergent lines of evidence derived from various fields of knowledge may be followed part way toward this goal, like those rays perceived through the telescope on the full moon near the margin of its visible hemisphere, which converge toward craters on the side of the moon that no eye shall ever see.

Developments in various branches of science during recent years have enabled us to draw a picture showing, as yet none too clearly, what the interior is like. Any progress that may have been made is due to the joint effort of many investigators, in the laboratory and in the field. The measurements and observations have been interpreted through the medium of physics, of chemistry and of mathematics. The important part played by these exact sciences in the study of the earth was recognized many years ago. For example, the Advisory Committee on Geophysics of the Carnegie Institution of Washington in 1902 stated in its report: "The phenomena presented by the earth are the historical products of chemical and physical forces."

[1] Joseph Barrell, Chapter I in "The Evolution of the Earth." R. S. Lull and others. New Haven, 1919.

Sources of Information

We now proceed to discuss briefly the various sources of information concerning the earth's interior and to list the more important bits of evidence, which may be joined together to give us a notion of the constitution of the earth as a whole.

The surface of the earth has been thoroughly explored, and what lies just below the surface of the land masses has been carefully and patiently studied by geologists for many years. Thanks to the dissection of the surface by erosion, notably in deep canyons, we are able to learn much about the materials down to a depth of several thousand feet, so that we now have an accurate picture of the rock masses that lie below the superficial layer of soil and sedimentary rocks. Underneath this thin veneer there is mainly igneous rock, that is, rock that has solidified from molten magma. According to Clarke's estimate, the outer 10 miles of the earth consist of 95.0 per cent. igneous rock, 4.0 per cent. shale, 0.75 per cent. sandstone and 0.25 per cent. limestone. The labors of the geologist have given us a store of information concerning the structure and mineral composition of rocks and the interrelations of the various formations. Although there are an overwhelming number of rock types, with respect to composition and texture, curiously enough a predominating amount of the visible igneous rock is either granitic or basaltic. The land surfaces occupy only about one fourth of the area of the globe. Unfortunately little as yet is known about the rocks of the remaining three fourths, although something may be inferred from the geology of the ocean bottom by observations on oceanic islands. Direct sampling of the ocean floor has been limited to a few inches in depth until quite recently, the depth having now been extended to several feet.[2]

[2] C. S. Piggot, *Bull. Geol. Soc. Amer.*, 47: 675–684, 1936.

Supplementing the facts of geology, the phenomenon of volcanism yields important information concerning what we may call the near interior. The existence of volcanoes and the outpouring of vast quantities of hot gases and molten lava furnish direct and striking evidence of conditions many miles below the surface. Additional information of value has been supplied by measuring the temperature of lava lakes, of lava flows and of the gases emerging from fumaroles. Further evidence of a hot interior is derived from the measurement of temperature in deep mines and boreholes. The temperature increases steadily with depth, but for reasons yet unknown the temperature gradient varies within wide limits from place to place in the earth. It may increase as much as 1° C. for each 18 meters or as little as 1° C. for over 100 meters. According to Van Orstrand,[3] the greatest depth attained in any boring is 12,800 feet (in Upton County, Texas); the highest temperature that has been measured is 118° C. in California at a depth of 9,000 feet.

Astronomy yields data of high precision concerning the motion of the earth, from which can be calculated its moment of inertia. The precession of the equinox was discovered by the Greek astronomer Hipparchus in 134 B. C. From the accurately known value of the constant of precession, it follows that the moment of inertia of the earth about the polar axis is 8.06×10^{44} g cm^2. This is a quantity that depends on the distribution of density within the earth. For a given mass, and for a given mean density, the moment of inertia depends on the distribution of light and heavy substances; if there is heavy material at the center and light material at the surface, the moment of inertia would be considerably less than if the central density were smaller than that of the surface. The moment of inertia of a body may be described qualitatively as its tendency to continue

[3] C. E. Van Orstrand, personal communication.

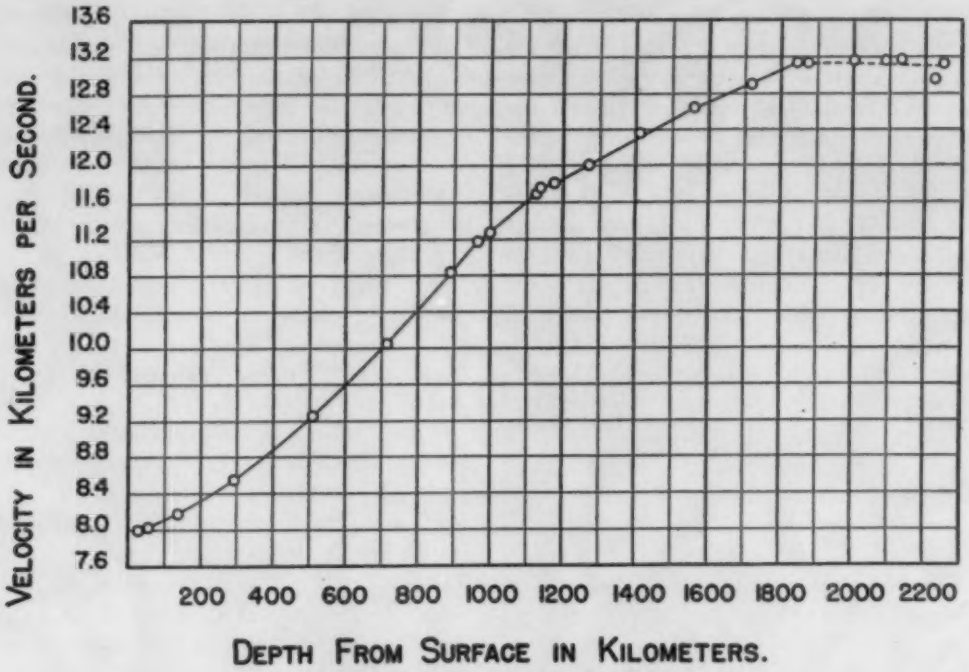

FIG. 1. VELOCITY-DEPTH CURVE

(AFTER REPETTI). SUCH CURVES SUPPLY DIRECT EVIDENCE CONCERNING THE NATURE OF THE EARTH'S INTERIOR.

spinning when once it has been set in motion. It is obvious that a fly-wheel loaded at the center will spin less persistently than if the same load were fastened to the rim. Similarly, the known moment of inertia of the earth allows us to make important deductions concerning the mass or density at various positions from surface to center.

By far the most direct and definite evidence concerning the interior of the earth is supplied by earthquake waves, especially in combination with laboratory measurements on various rocks and minerals. The story has been told before, but it will bear brief repetition. When an earthquake occurs, elastic vibrations of various kinds are generated. One variety travels along the surface and is responsible for the damage caused by large earthquakes. More important for the present purpose are the two varieties that pass through the body of the earth. One of these "through-waves" consists of longitudinal vibrations, analogous to ordinary sound waves in air; the other consists of transverse vibrations, more nearly akin to light waves. Their formation is in accord with the conclusion from the theory of elasticity that any disturbance in an elastic isotropic material should give rise to the two kinds of vibrations, traveling with velocities depending only on the density and elastic constants of the material at each point. Earthquake waves, which have passed through the earth, are recorded by the delicate instruments of the seismologist, who is able to distinguish the several types of waves and to tell with high precision their time of arrival at various stations. From the observations we may construct for each kind of wave a "travel time"-distance curve, which shows for any distance the time required for the vibrations to pass from the earth-

quake center to the recording instrument. The mathematician is now called upon. After subjecting the curve to a remarkable and intricate mathematical analysis he finds the shape of the path along which the wave travels—it turns out to be curved—and finds also the velocity at each point of its path, that is, the velocity at the various depths to which the wave has penetrated in its journey through the earth from focus to station. The recent careful determinations of Repetti[4] are shown in Fig. 1. The particular value of this velocity-depth relation lies in the fact that solely from laboratory measurements of the elastic contents of rocks (to which reference will be made later) we may calculate the wave velocity in various types of rocks, and thence, by comparison with the known velocities at several depths below the surface, make important deductions concerning the nature and composition of the material within the earth. It is as if the earthquake waves, upon arriving at the surface, carry with them a message telling not only how long they have been on the way and how deep they have penetrated, but also how fast they traveled at each point of their path, and finally the nature of the material through which they have journeyed. To be sure, the messages are in code, but happily the code has been deciphered by the ingenious devices of the mathematician.

Turning now to those laboratory measurements that pertain to the present subject, we note first the constant of gravitation, originally determined by Cavendish in the eighteenth century. The most recent published result, that of Heyl,[5] is 6.67×10^{-8} in absolute units. From the measured constant of gravitation we know at once the total mass of the earth, and thence by combination with its volume, the average density of the globe. The value obtained, 5.52, is a very important one to which reference will be made later.

The chemical composition of the rocks in or near the earth's surface has been subjected to exhaustive investigation. It is a striking fact that, although about one thousand different minerals are known, the importance and essential igneous rock-forming minerals number only about a dozen, and that although some 90 chemical elements have been found in or on the earth, 11 elements make up 99⅛ per cent. of the earth's layers. These elements in order of their abundance are: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium, titanium, phosphorus and hydrogen. The above conclusions are based on the studies of Washington and others of nearly 10,000 chemical analyses of rocks, which show also that the average igneous rock found at the surface of the earth corresponds to a granite or granodiorite.

Of especial significance is the composition of meteorites. As a result of many analyses of these strange visitors from outer space we now know that they consist largely of impure metallic iron and basic silicates approaching olivine in composition. Absent, or present only in minor amounts, are the characteristic constituents of granite, such as lime, alumina and the alkalis.

An indispensable item in the list of factors from which we hope to reach definite conclusions concerning the earth's interior is the compressibility of rocks. One of the earliest grants of the Carnegie Institution of Washington was to F. D. Adams, at McGill University, for the purpose of measuring the elastic constants of typical rocks.[6] The results obtained were of great interest and value, although the method used was an indirect one and the maximum pressure that was applied to the rock specimens was only a few hundred atmospheres. Subsequently attempts were made by several

[4] Wm. C. Repetti, Dissertation, St. Louis University. (Printed in Manila, 1930.)

[5] P. R. Heyl, *Bur. Standards Jour. Res.*, 5: 1243, 1930.

[6] See F. D. Adams and E. G. Coker, Carnegie Inst. Wash., Publ. No. 46.

investigators to measure the cubic compressibility of rocks subjected to pure hydrostatic pressure. This sort of measurement is beset with many difficulties. The effect of pressure on the volume of solids is very small. For most rocks it is between one and two parts per million per atmosphere, and it is desired to measure this small effect with an accuracy of 1 or 2 per cent. Satisfactory results were obtained several years ago at the Institution's Geophysical Laboratory by the use of high hydrostatic pressures—10,000 atmospheres or more. High pressure, under hydrostatic conditions, has three important advantages: first, because the pressure conforms more nearly to the conditions at great depths below the surface of the earth; second, because the volume changes, which are so small when only one atmosphere is available, are multiplied 10,000 times; and third, because by the use of high pressures we avoid the irregularities that appear at low pressures, especially with coarsely crystalline materials.

For these measurements the so-called piston-displacement method was used. The specimen, usually cylindrical in form, was placed inside a thick-walled cylinder, or bomb, of special steel, where, entirely surrounded by a thin liquid, it was subjected to the desired pressure. A piston with a leak-proof packing was forced into the bomb by means of a press and the pressure thus built up. The amount of movement of the piston is obviously a measure of the volume-change of the material within the bomb. Therefore, by recording the motion, or displacement, for a series of pressures, and correcting for various factors such as the compressibility of the liquid, we obtain finally the compressibility of the specimen.

Although it would be desirable to have similar direct measurements of the rigidity of rocks, a substitute is afforded by the above-mentioned seismologic data, which show that the material at considerable depths is sensibly isotropic and that the elastic constant called Poisson's ratio has the nearly constant value, 2.7. This justifies the use of a simple relation in the theory of elasticity to calculate the rigidity of rocks at high pressures from the compressibility measurements, and thence to calculate the velocities of the transverse and longitudinal vibrations.

Over a period of several years many such measurements and calculations have been made on numerous varieties of granite, diabase and other rocks, and on the common rock-forming minerals. The immediate conclusions from the results were first, that typical rocks had a much lower compressibility, and hence a much higher wave velocity, than had previously been supposed; and second, that except for very low pressures the compressibility of a given rock was merely the average of the compressibilities of its component minerals.

The above-mentioned results were obtained at or near room temperature. Quite recently Birch and Dow at Harvard have been able to carry out measurements at elevated temperatures and thus to supply information concerning the effect of temperature on elasticity and wave speed in rocks.[7]

Brief mention will be made of one other experimental research, which is pertinent to the general subject before us. This is an investigation of the effect of high pressure on the critical temperature at which iron loses its magnetism. It was carried out as a joint effort of two branches of the Institution, the Department of Terrestrial Magnetism and the Geophysical Laboratory. At or above 768° C, iron loses its strong magnetic properties. Any masses of metallic iron within the earth are subjected to the combined effect of high pressures and temperatures. In order to learn something as to the possibility that deep-seated

[7] Francis Birch and Richard B. Dow, *Bull. Geol. Soc. Amer.*, 47: 1235–1255, 1936.

metallic iron, despite a presumably high temperature, should still be strongly magnetic, measurements of critical temperature of magnetization of iron and other ferro-magnetic materials at pressures up to 4,000 atmospheres were carried out. The final result, that the effect of pressure on the critical temperature was practically *nil*, or probably no greater than 0.001° C. per atmosphere (for pure iron),[8] will be referred to presently in connection with the core of the earth.

The Interior of the Earth

The observations and experiments that have been described have not been intended merely as a partial list of unrelated facts in the field of geophysics. They are the main clues by which we are enabled to solve, at least partially, the problem of the structure of the earth's interior. We are now quite certain that the earth consists of three principal regions or zones, the core or central region, the crust or superficial layer and the intermediate zone.

That the material of the earth near its center must be very heavy was one of the earliest conclusions and an excellent example of deductions concerning the interior. Since the average density of the earth as a whole is 5.5, as determined from the measured constant of gravitation, and since the average density of rocks found at the surface is only about 2.8, it is obvious that the central density must be much higher than 2.8—perhaps 8 or 10 or 12—in order for the average to come out right. This high density in the central region might be due to either of two causes: (1) The squeezing of ordinary rock into a much smaller volume under the enormous pressure due to the weight of superincumbent material, or (2) the presence of some other, intrinsically heavier, substance such as a metal.

[8] L. H. Adams and J. W. Green, *Phil. Mag.*, 12: 361–380, 1931.

The first alternative was eliminated by using seismologic data to tell us the compressibility of rocks at great depth and then computing the amount by which the volume of silicate rocks could be reduced at depths well toward the center. The maximum by which the density of the material could be increased turns out to be surprisingly large, but entirely inadequate for giving the required average density of the earth. We must conclude, therefore, that it is impossible to account for the high density of the earth by compression alone, and that at and around the center there is a considerable amount of an intrinsically heavy substance. The only reasonable choice is metallic iron. This element is the fourth in order of abundance in ordinary rocks, it is also abundant in the sun as shown by the spectroscope, and in both the metallic and combined form it is the dominant constituent of meteorites. By analogy with meteorites we should expect that the core would not be pure iron but rather an alloy of iron with several per cent. of nickel. The notion of an iron core is not a new one; it was suggested by Dana in 1873, and developed by Wiechert and others in later years. Still earlier the earth was considered to be a great ball of granite, chemically homogeneous throughout, but we have now passed beyond what may be called the granitic era in geophysics, and our present convictions are based on quantitative evidence of the presence of some heavy material at the center.

We may therefore speak with confidence of an iron or nickel-iron core the diameter of which is fixed by seismologic data at 6,400 km, or a little more than one half the diameter of the earth, and confirmed by the moment of inertia determined by astronomical observations. The core is plastic rather than rigid, since it does not transmit transverse earthquake waves; it is non-magnetic and therefore has no appreciable influence on

the earth's magnetism; and the pressure at its center, as is easily calculated, reaches the enormous value, 3,200,000 atmospheres. We know the core to be very hot, but it has not yet been possible to arrive at an entirely satisfactory estimate of the central temperature. From considerations connected with the origin of the earth, the conclusion has been reached[9] that the temperature in the far interior is of the order of 3,000° C.

Although the existence of an iron core is generally accepted by those who have interested themselves in the subject, a few investigators have doubted the validity of this conclusion. Ono, for example, prefers to explain the high central density by the combination of atoms under the conditions of high pressure and temperature to form heavier atoms of various kinds. Others have inclined to the belief that under sufficiently high pressures the structure of all solids will collapse, leaving a material of the same chemical composition and greatly increased density.

This reminds one of the heated discussion carried on some years ago in the columns of a magazine devoted to popular science, as to whether the water at the bottom of the ocean was as dense as cast iron. One faction contended that engineering data showed that materials or structures subjected to sufficient compression in a testing machine invariably failed by crushing, and that at considerable depths in the ocean the water would crush, or cave in upon itself, and thus become as dense as a heavy metal. The principle that was overlooked in this contention was that it is relatively very difficult for pure hydrostatic pressure to make a structure collapse. It is true that we must be on guard against applying the experience and conclusions pertaining to a limited range of pressures and temperatures to the extreme conditions prevailing in the interior of the earth. On the other hand, various considerations indicate that the postulated transmutation of elements and collapse of crystal structure will take place only under pressures and temperatures of a higher order of magnitude than those existing in the earth, that is to say, in the interior of stars rather than planets.

Passing over the intermediate zone for the moment, let us turn our attention to the outer layer, commonly called the crust. This term dates back to the time when the earth was thought to consist of a thin solid crust surrounding a molten interior. But the notion of a true crust floating on a thin liquid is now abandoned, although the word is still used to designate the outer layer, perhaps 40 or 50 kilometers thick, with properties very different from those of the material below it.

From geologic studies it has long been known that the accessible part of the crust consists largely of granite. When the measurements of the compressibilities of rocks, already referred to, were made and the velocity of longitudinal vibrations in typical granites found to be 5.6 kilometers per second, it was therefore a source of gratification to find that this was precisely the speed found by the seismologist for the longitudinal waves in the outermost parts of the crust. From seismologic data we know that this granitic layer varies in thickness from place to place. In continental areas it may be as little as 10 kilometers or as much as 30 kilometers in thickness, while in the great ocean basins it appears to be entirely missing.

Underneath the granitic layer the crust, as indicated by the velocity of earthquake waves passing through this region, is basaltic in composition. There is some evidence for a transition layer intermediate in composition and position, but apparently the crust consists largely, if not entirely, of the granitic and basaltic layers.

[9] Personal communication from Dr. Ross Gunn.

By the mathematical theory of heat conduction the temperature throughout the crust may be estimated if three principal factors are known. These are: (1) the age of the earth, (2) the average amount of radioactive substances in the superficial rocks and (3) the temperature gradient at the surface. The age of the earth, that is, the time that has elapsed from the initial solidification to the present time, is probably not far from 2,000 million years, since minerals have been found, whose age as determined by the lead-uranium ratio is 1,500 million years, and since from astronomical considerations an upper limit of 3,000 million years is indicated. The average amount of radium in the rocks found at the surface is about 3 parts in a million million and the average temperature gradient in undisturbed regions is 0.03° C. per meter. Although these items are all subject to considerable uncertainty, they allow us to construct a useful curve, showing how temperature varies with depth. Especially striking is the conclusion that below about 300 kilometers the temperature is nearly the same as it was originally; the greater part of the earth is now as hot as it was when solidification first took place.

The accessible portion of the crust is almost entirely crystalline. Glassy or amorphous material is comparatively rare. Whether the deeper parts of the crust are crystalline or glassy is a question upon which there is not yet complete agreement. It is worth while to note that the question can not be answered by referring to the temperature-depth curve already mentioned, because the only such curves that have been constructed were based on the supposition that the termination of the era of free convection and the initial cooling of the earth as a solid body were coincident with the freezing of the molten magma.

The intermediate zone 2,000 miles in thickness extends from the bottom of the crust to the top of the iron core (see Fig. 2). Its striking features are the major discontinuities in the velocities of earthquake waves at the upper and lower boundaries. Passing from the crust down through the upper surface of this region, longitudinal waves suddenly increase their speed to 8 kilometers per second. The laboratory measurements on the elasticity of rocks, mentioned above, indicated that only two kinds of rock could support so high a velocity at the moderate pressures appropriate at a depth of about 50 kilometers. These are dunite and eclogite, rocks that are found in few places at the surface of the earth. Weighty evidence pointed to the first of these as the more probable constituent of the intermediate zone, and the conclusion was drawn that the shell consisted of this olivine rock and that therefore the whole earth, except for the iron core and the relatively thin crust, was made up entirely of magnesium iron orthosilicate. It followed that only four elements, silicon, oxygen, magnesium and iron, composed the bulk of the earth's substance, all the other elements being present in minor amounts.

The force of this conclusion has been weakened somewhat by the recent measurements of Birch and Dow, mentioned above, on a specimen of diabase from Vinal Haven. The result obtained for the compressibility leads to a wave velocity equaling that found in the upper part of the intermediate layer, and thus appears to invalidate the argument that the presence of dunite or peridotite in this region is necessary in order to account for the observed velocities of earthquakes below the bottom of the crust. The method used was a linear one, the cubic compressibility being inferred from the change in length of a small rod exposed to pressure, whereas at the Geophysical Laboratory the volume-change, being measured directly, is independent of the degree of isotropy of the material. In view of the fact that the two methods

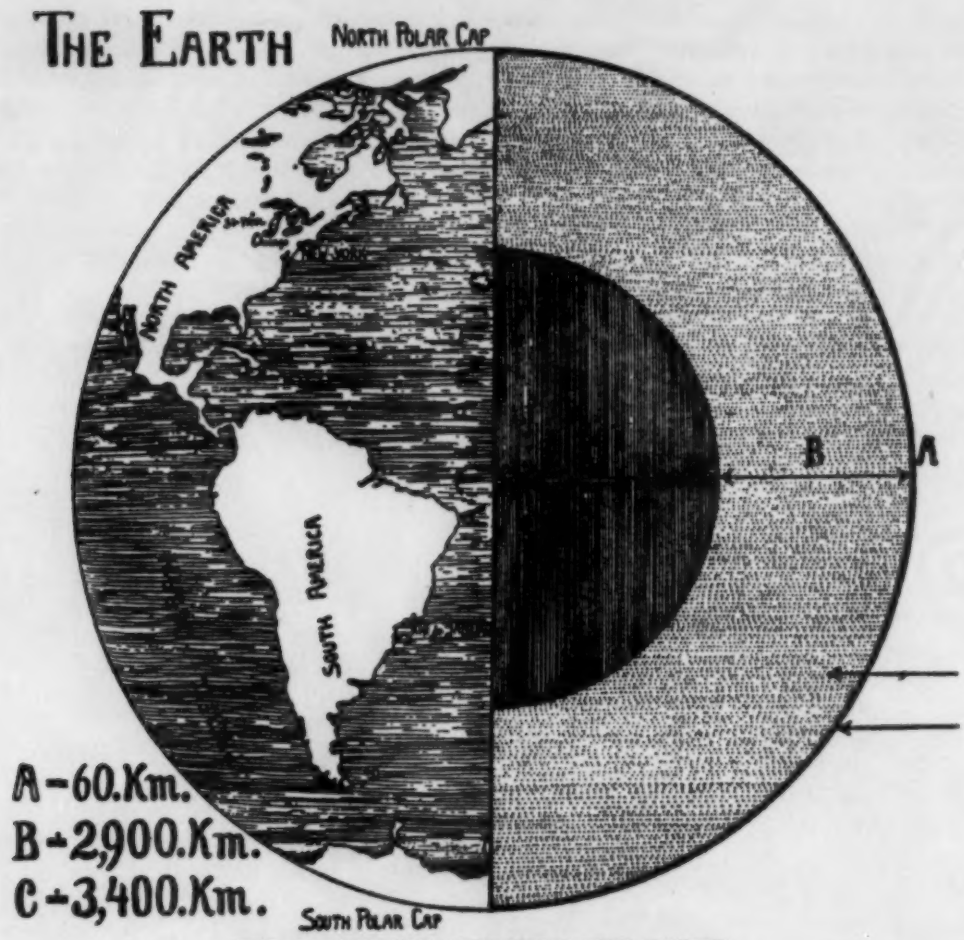

FIG. 2. SECTION THROUGH THE EARTH

(AFTER MOHOROVIČIČ). *A* IS THE CRUST, *B* THE INTERMEDIATE ZONE, AND *C* THE CENTRAL CORE.

agree remarkably well for non-porous substances such as silica glass and also for the porous rock, limestone, the writer prefers to accept the results of direct volume-change measurement and the conclusions based thereon, at least until measurements by the linear method are made on specimens of diabase cut in three mutually perpendicular directions, and until further measurements by both methods on the same samples of rock become available.

From observations on the tidal deformation of the surface the earth has long been known to be as rigid as steel, and from seismologic data we find that from crust to core the rigidity increases steadily with increasing depth. It is very clear, therefore, that the earth as a whole is "solid"; but whether its substance, particularly in the intermediate zone, is crystalline or glassy is more difficult to decide. From what information we have it does not seem possible that any silicate glass of a composition favorable for remaining permanently in the glassy state can support the requisite wave velocities. Although there may be, and probably are, shallow zones or limited regions of glassy material, the weight of evidence, in the writer's opinion, seems to favor crystallinity for

practically the entire silicate part of the earth. This is a subject for which admittedly there are decided differences in the viewpoints of various investigators. Lack of space prevents a complete discussion of the subject at this time.

Many circumstances, concerning which there is at the moment insufficient time for discussion, indicate that the early history of the earth was as follows: The primitive molten magma consisting mainly of magnesium iron silicates with smaller amounts of other oxides, including water, together with a considerable amount of metallic iron, first separated into two layers—molten iron below and silicate magma above. The silicate layer then began to crystallize at the bottom. As the solid layer increased in thickness, the minor constituents, including water, were concentrated to a greater and greater extent in the remaining liquid. Finally when the liquid layer had been reduced to a thickness of a few tens of kilometers, and was much richer in the originally minor constituents, the crust of the earth was formed.

One of the most cogent reasons for believing that the earth is crystalline is that in no other way can we easily account for the fact that the crust differs so markedly from the interior. Granting that the earth was once molten and well stirred, we apparently must admit that the separation into zones on so large a scale took place either by the falling of a heavy insoluble liquid to the bottom (thus producing the iron core) or by the residuum of a process of crystallization, this residuum becoming the crust.

Concluding Remarks

The problem of the earth's interior has not yet been solved. Although much is known about conditions far within the earth the interior still holds many mysteries. An explanation of the mechanism by which deep-focus earthquakes occur is lacking, and we have no clues as to the underlying cause of the numerous minor discontinuities in the earthquake velocity-depth curves. Better knowledge of the temperatures within the earth would be of great utility and, especially, some basis for a more precise estimate of the original temperature of the molten earth. A general understanding of the great intermediate zone is essential before we can make satisfactory progress in investigations of the crust.

But although much remains for the future, we are able to point to a number of definite accomplishments during the past several years. These are: (1) precise measurement of the elastic constants of rocks and the determination of the speeds with which elastic waves will travel through them; (2) the identification of the upper half of the crust as a granitic layer; (3) a demonstration that the core of the earth contains a heavy material such as iron; (4) an explanation of the two major discontinuities within the earth in terms of the elastic constants of typical rocks; (5) the supplying of strong evidence that large masses of iron may exist in the interior without influencing the earth's magnetic field, and (6) the establishment of an improved temperature-depth curve for the crust and the region immediately below it.

In attempting to paint a picture of the deeper parts of the earth, the best we can do at present is to draw the outlines. Perhaps future developments may enable us to make a bolder drawing and even to fill in something of form and color.

PHYSICS IN THE ATTACK ON THE FUNDAMENTAL PROBLEMS OF GENETICS[1]

By Dr. H. J. MULLER

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THE evidence obtained by geneticists indicates that it is in the tiny particles of heredity—the genes—that the chief secrets of living matter as distinguished from lifeless are contained, that is, an understanding of the properties of the genes would bridge the main gap between inanimate and animate. Such a study would be of intense interest from the point of view of physics as well as of physical chemistry and organic chemistry, for it is already known that these genes have properties which are most unique from the standpoint of physics and of the sciences related to physics. So peculiar are these properties that physicists, when first confronted with them, often deny the possibility of their existence. Yet there is really no doubt of the truth of the biologists' findings concerning the genes, so it may well be that an elucidation of them may throw light not only on the most fundamental questions of biology, but even on fundamental questions of physics as well. I am therefore making this plea to physicists in the hope that they will interest themselves more actively in these problems, of such vital importance to both our fields.

To grasp the problems involved in the study of the gene it should first be explained that genes are particles of submicroscopic volume, probably of the order of about one twentieth of a micron in length, and considerably less in their other diameters, probably of protein composition (see below), and bound to one another in line, single file, so as to form solid threads ("chromonemas"). These threads are usually many microns long and thus comprise thousands of these genes, each gene in the chain usually being different in its composition and chemical function in the cell from every other gene. The nucleus of the cell contains a specific number of these gene-chains, often in more or less spirally coiled form. All these genes not only exist in the reproductive cells and constitute the ultimate particles of heredity, but they also exist in all the other cells of any living body and, as mentioned in the preceding, they probably constitute the ultimate particles of life itself. Through the varied reactions of the different kinds of genes with the various surrounding materials of the protoplasm, the basis is laid for the production of the various chemical substances and for the carrying on of the various chemical processes, and for the determination of the various morphological structures peculiar to each cell.

Now, the most spectacular property of the gene, from the standpoint of physics, is its property of *specific auto-attraction* of like with like. In explanation of this, no physicist has ever yet been able to offer any plausible hypothesis. The attraction in question has an opportunity of exerting itself, owing to the fact that in most cells there exist at least two gene-chains of each kind (one having been originally derived from the mother of the organism, the other from the father). That is, if we may represent the genes in one of the gene-chains in a cell as A, B, C, D, etc., in that

[1] Paper presented to session on physics of the Academy of Sciences of the U. S. S. R., Moscow, March, 1936.

order, then there is present somewhere else in that cell another gene-chain having genes of identical composition: A, B, C, D, etc., in the same order. Besides this, there are other gene-chains which we may represent as L, M, N, etc., T, U, V, etc., and of each of these long chains or chromonemas the cell contains two representatives. Now, under certain conditions, it becomes evident that each gene forms the center of a specific field of attractive force, for then gene A tends to come together with the other A, B with the other B, (L with L, M with M, and so on). We know that this must be true, even though the individual genes are too small for us to see, because we can see that the gene-chains as a whole tend to come together in this way, like with like, so that one ABCD comes into side-by-side contact ("conjugates") with the other, one LMN with the other LMN, etc. They always do this in such a way as to be oriented in the same direction, the A end of one chain next to the A end of the partner chain, not next to the other end. Moreover, if through some prior accident one or more of the chromonemas (gene-chains) has previously become broken at any point (or even if several breaks have occurred and the fragments have then united together again in a different way than before, so as to have the genes arranged in a new order), still the corresponding segments tend to come together, like with like. Thus the attraction is in no wise a property of the chain as a whole but purely of the individual, constituent genes.

Unlike the ordinary forces of adsorption known to the physical chemists, these gene forces are of such range as to act over visible microscopic distances. In doing so, moreover, they must in some way interpenetrate one another in many directions, since the forces of attraction of many genes must be traversing the same space at the same time. And despite this interpenetration, these forces must somehow preserve their directions and their specificities. It is probable that this force of auto-attraction exists, to some extent at least, at all times, but it is sometimes prevented from expressing itself by the simultaneous existence of a non-specific repelling force of a different nature, the latter probably caused by electrical charges. It has not yet been found feasible under the conditions of biological work to make quantitative studies, after the physicist's fashion, of the nature of the force of gene attraction: studies of its variation of intensity with distance; of the effect of varying conditions upon it; of its direction; of its speed of propagation; of the possible interference with one another of the forces emanating from different genes; of its possible polarization, etc. It is probable, however, both from theoretical considerations and from the observed tendency of like strands to conjugate by twos, even when more than two are present, that the force does not issue in a radially symmetrical manner but that a certain side-surface of the gene tends to attract a specific side-surface of the other, like gene. We would like physicists to search the possibilities of their science and tell us what kind of forces these could be, and how produced, and to suggest further lines of approach in their study.

It is not unlikely that a solution of the above physical mystery would also throw much light on the nature of that property of the gene which is most peculiar and spectacular from the standpoint of the chemist. This second peculiar property is that of *auto-synthesis*. That is, each gene, reacting with the complicated surrounding material enveloping all the genes in common, exerts such a selectively organizing effect upon this material as to cause the synthesis, next to itself, of another molecular or supermolecular structure, quite identical in composition with the given gene itself.

The gene is, as it were, a modeller, and forms an image, a copy of itself, next to itself, and since all the genes in the chain do likewise, a duplicate chain is produced next to each original chain, and no doubt lying in contact with a certain face of the latter. This gene-building is not mere "auto-catalysis," in the ordinary sense of the chemist, since reactions are not merely speeded up that would have happened anyway, but the gene actually initiates just such reactions as are required to form precisely another gene just like itself; it is an active arranger of material and arranges the latter after its own pattern.

The analogy to crystallization hardly carries us far enough in explanation of the above phenomenon when we remember that there are thousands of different kinds of genes, *i.e.*, of genes having different patterns, in every cell nucleus, and that each of these genes has to reproduce its own specific pattern out of surrounding material common to them all. When, through some micro-chemical accident, or chance quantum absorption, a sudden change in the composition ("pattern") of the gene takes place, known to biologists as a "mutation," then the gene of the new type, so produced, reproduces itself according to this new type; *i.e.*, it now reproduces precisely the new pattern. This shows that the copying property depends upon some more fundamental feature of gene structure than does the specific pattern which the gene has, and that it is the effect of the former to cause a copying not only of itself but also of the latter, more variable features. It is this fact which gives the possibility of biological evolution and which has allowed living matter ultimately to become so very much more highly organized than non-living. It is this which lies at the bottom of both growth, reproduction and heredity. We would like the physical chemists to work on this problem of auto-synthesis for us, but it may well be that a further elucidation, by the physicists, of the property of auto-attraction of genes would greatly help in the explanation of this auto-synthesis also.

The reason why I think there may be a relation between the two properties is this. If the attracting principle of like for like, which we already know to be possessed by the gene considered as a whole, extend also to more elementary parts of the gene, to "blocks" whose differences in arrangement constitute the specific differences in gene pattern whereby one gene differs from another and which form the basis of the mutational changes, then, if we suppose that representatives of these more elementary "blocks" exist in scattered disorganized form in the space surrounding the genes, it can be seen that each gene-part or "block" would tend to attract to itself another, like part, and so a second group of parts would gather next to the original gene in the same pattern as in the latter, in much the same way as, on a still grosser scale, each chromonema as a whole builds up a second chromonema, having its individual genes identical with and arranged in the same order as in the first one. If, then, the auto-attraction holds not merely for genes as a whole but also for gene-parts the auto-synthesis of a gene as a whole would be largely explained in terms of this auto-attraction. (Of course we should in this case still be left with the problem of the synthesis of the gene-parts, but this might be simpler as they might be of relatively limited number). It is tempting to think that this suggestion is true, in view of the great uniqueness both of the property of auto-attraction and of auto-synthesis, and in view of the possession by both of certain common, striking features: namely, auto-specificity, and the property of retaining this auto-specificity in spite of the changes called mutations. For it is to be noted that in the case of the auto-attraction also, we must suppose

that when one of those rare changes called a mutation occurs, the new gene has a changed kind of attraction, such that it now attracts preferentially another gene having a pattern like that of its new self, not one with a pattern like that of its old self. Thus, the auto-attraction of the gene, just like its autosynthesis, must depend upon some fundamental features of the gene structure, which persists despite the secondary changes in pattern (mutations). And this fundamental feature must be instrumental not only in producing an attractive force in general, but in determining that this attraction shall somehow express, in its specificity, both the fundamental structure itself and also those other details of pattern which vary independently of this fundamental structure. In the face of such problems, the biologists must perforce call to the physicists and the physical chemists.[2]

In the solution of these problems, and of the general problems of gene composition, one possible line of approach might be through the study of x-ray diffraction patterns. Preliminary studies of this nature upon the proteins of hair have been made by Astbury and others,[3] at Leeds, but studies of such proteins may be a far call from the study of the gene. But it may be possible for gene material to be used in such investigations. For there exist, in some of the cells of flies, bundles of identical chromonemas conjugated together in hundreds, and these bundles are so large that they might even furnish material for an x-ray diffraction study if we had people of sufficient physical training, combined with biological interest, to tackle such a job. Of course, there may be much material extraneous to the genes themselves, contained in such a bundle of chromonemas, but they are at least more nearly the material we are seeking than is any other morphologically separable constituent of the cell. It might also be objected that every gene is different from every other, along the length of the chain, and that therefore we would be studying, at best, a great mixture of gene materials. Nevertheless, as above stated, there must be much in common to the structure of all genes and these common features might give results in such a study. Needless to say, it would also be desirable to have parallel studies on such material carried out by the methods of the chemists.

In the past year the opportunity has also arisen of obtaining from another source material which may serve our present purpose. This possibility arises out of the discovery by Stanley and Loring,[4] that the substance (or "organism") causing the so-called mosaic disease of tobacco, and likewise that of tomato (and doubtless of various other higher organisms), may be obtained in crystalline form, apparently as a pure protein. We judge that this material has the properties of a gene, inasmuch as it can reproduce itself, *i.e.*, it can undergo autosynthesis when present in a cell and it is probably mutable, since different "species" of it are known. We may provisionally assume, then, that it represents a certain kind of gene. The weight of its giant molecule is of the order of several million, and this agrees as well as could be expected with the very approximate estimates of size hitherto made for the genes of flies. As this substance can be obtained in some bulk and in apparently

[2] Discussions of gene auto-attraction and autosynthesis have been given by the author in the following papers: H. J. Muller, *Am. Nat.*, 56: 32–50, 1921; *Proc. Int. Cong. Plant Sci.*, 1: 897–921, 1929; "The Enigma of the Gene and of Its Mutation," address at Franklin Institute, Philadelphia. (MS. unpublished, 20 pp), December, 1928; *Am. Nat.*, 69: 405–412, 1935.

[3] W. T. Astbury and R. Lomax, *Jour. Chem. Soc.*, June, 1935. W. T. Astbury and W. A. Sisson, *Proc. of Royal Soc. London*, 150, pp. 533–551, July, 1935. W. T. Astbury and H. J. Woods, *Philo. Trans. Royal Soc. London*, 232, pp. 333–394, June, 1933.

[4] W. M. Stanley, *Science*, 81: 2113: 644–645, 1935; W. M. Stanley and H. S. Loring, *Science*, 83: 2143: 85, 1936.

pure form, it will be very important to carry on an active investigation of it not only from a purely chemical standpoint, but also from a physical standpoint, with special reference to the problems above raised. Among other things, x-ray diffraction studies of it should be attempted by competent specialists in this field of physics.

I have tried in the above to lay emphasis on the most outstanding problems of physical and physico-chemical science which the geneticist has found himself confronted with, and which he is practically unable to attack by means of the methods familiar to him. I have omitted a discussion of the very important problem of the way in which changes in genes —mutations—occur. Although this is a matter in which the aid of physicists is invaluable to us, the methods of genetics and physics combined—investigations of the frequency and character of mutations under varying conditions and with varying doses of irradiation—have already given valuable results. They have shown, for example, that the mutations produced by high frequency irradiation are the results of single ionizations, and that the whole process from ionization to mutation must be rather sharply circumscribed in space. Through such studies we may be able to learn more about the nature of these variable features of the gene pattern, which determine the specific properties of one gene as distinguished from another one, and which are in a sense independent of those fundamental features of its composition which give it its properties of auto-attraction and auto-synthesis. It is in this field of mutation that the physicist is to-day most actively and fruitfully helping the geneticist.

There are also many other physical questions before the geneticist, such as that of the nature of the non-specific repulsive force which exists between chromonemas, especially at certain periods and in certain portions of them; the nature of the coiling and uncoiling of these threads and of all the various motions and physical and physico-chemical changes which they undergo in their complicated life history. There is the question of what holds the genes together end to end, in single rows; how these chains may become broken and the pieces stuck together again, etc. There is the question of the manner in which they produce their effects upon other substances in the cell—probably by a kind of enzyme action—so as to act as the determiners of the properties of the cell and of the organism as a whole. And there is the problem of the so-called "position effect," *i.e.*, the fact that the arrangement of the genes in the chromonema with respect to each other has an important influence upon the kind of effects which these genes exert upon the surrounding substances. Possibly this "position effect," too, is related to the property of gene attraction. All these questions, however, important though they be, nevertheless seem secondary in comparison with the problems of auto-attraction and of auto-synthesis themselves, and of the structure giving rise to them, and with the related problem of the nature of those changes (mutations) which the gene undergoes, which do not disturb these two properties. It is becoming recognized nowadays that the gene is the basis of life. These two properties, including the fact of their undisturbability by mutation, lie at the basis of the gene. The geneticist himself is helpless to analyze these properties further. Here the physicist as well as the chemist must step in. Who will volunteer to do so?

THE SENECA SOCIETY OF FACES

By WILLIAM N. FENTON

U. S. INDIAN SERVICE, TONAWANDA INDIAN RESERVATION, AKRON, N. Y.

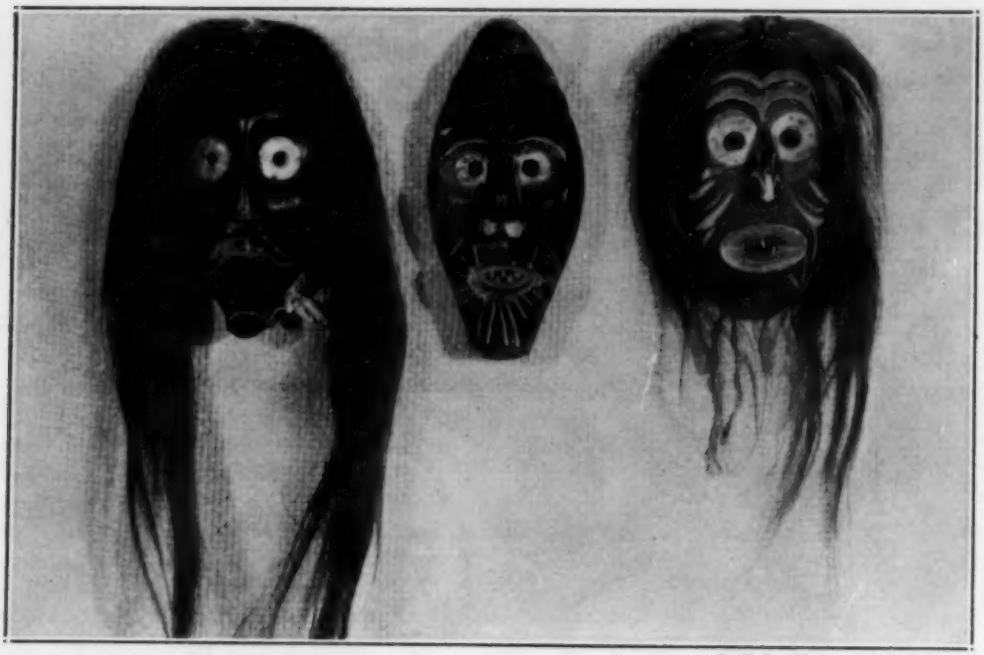
FOUR communities of Indians who live but a day's journey from New York City still put on wooden faces in order to drive disease from their settlements. At the Onondaga Reservation near Syracuse and on the three Seneca reservations neighboring Buffalo, there are modern Iroquois villages which still maintain old customs. The "real or longhouse people" reside about ceremonial structures called longhouses at Onondaga, Tonawanda, Coldspring on the Allegheny River and at Newtown on Cattaraugus Reservation. Some of the Iroquois tribes moved west of the Niagara River into Canada at the close of the American Revolution. There, on Six Nations Reserve along Grand River in Ontario, are Onondaga, Seneca and Cayuga longhouses which are still active. The New Yorker who wishes to catch glimpses of the past may, if he is accepted, witness ancient ceremonies almost in his dooryard without going to the Southwest.

THE WOODEN FACES

Wooden masks from the Iroquois are prominently displayed in exhibits of eastern museums. A few museum visitors may appreciate that the weird human likenesses which mock them from the show-cases are actually memorials to generations of nightmares. They are wooden portraits of several types of mythical beings whom the Seneca say only a little while ago inhabited the earth. The Seneca term for one is "Face" (gagǫ́hsa'); the Onondaga call him "Hunchback" (hadu'í'), and they are called "False Faces" in literature. Iroquois hunters when traveling in the forests frequently met strange, quasi-human beings. Later, these forest folk

THE SENECA LONGHOUSE AT COLDSPRING ON THE ALLEGHENY RIVER.

AT COLDSPRING AND OTHER CONSERVATIVE IROQUOIS COMMUNITIES, THE "REAL OR LONGHOUSE PEOPLE" LIVE CLUSTERED ABOUT A DANCE-HOUSE, CALLED THE LONGHOUSE, WHERE THEY GATHER FOR SOCIAL AND RELIGIOUS MEETINGS.



Buffalo Museum of Science.

ANCIENT MASKS, PRESUMABLY FROM THE CANADIAN IROQUOIS.

HEAVY CARVING, PROMINENT CHINS AND WRINKLES INLAID WITH COLORED PIGMENTS ARE CHARACTERISTIC ART OF THE MIXED CAYUGA AND ONONDAGA TRIBES AT GRAND RIVER AND, LESS FREQUENTLY, THE ONONDAGA AT SYRACUSE.

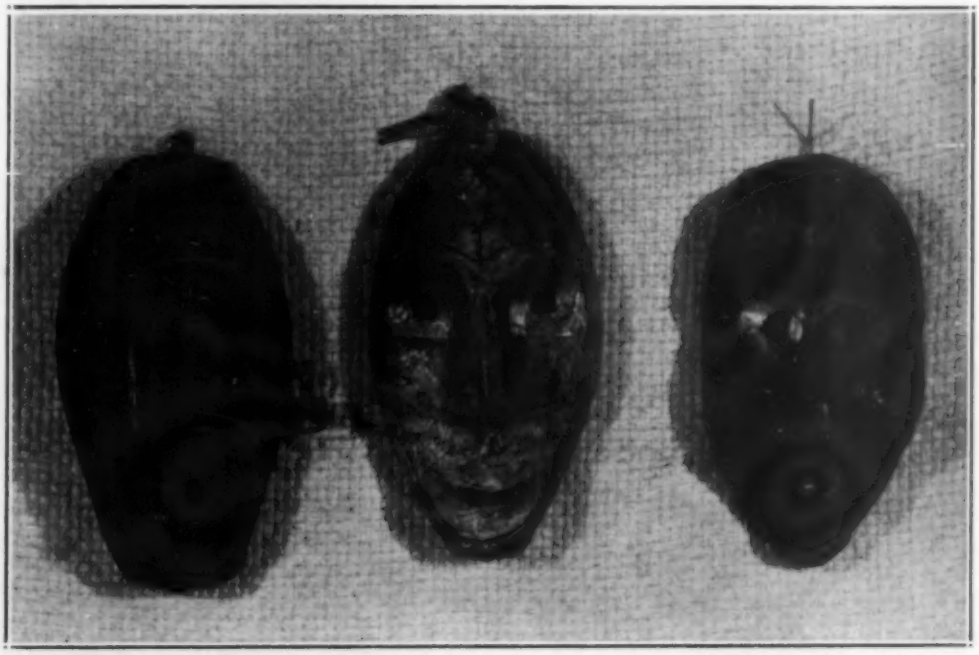
appeared to the hunters in dreams. They agreed not to molest humans, saying that they merely wanted Indian tobacco (*Nicotiana rustica*) and mush to be made from the white corn meal which hunters and warriors carried.

The Faces claimed to possess the power to control sickness. They instructed the dreamers to carve likenesses in the form of masks, saying that whenever any one makes ready the feast, invokes their help while burning Indian tobacco and sings the curing songs, supernatural power to cure disease will be conferred on humans who wear the masks. The dancers should carry turtle rattles and speak a weird, unintelligible nasal language. They can scoop up glowing embers in their bare hands, without suffering burns, in order to blow hot ashes on the sick person. The masks are as varied as the visions and the artistic whims of the individual craftsmen who have carved them from single blocks of living basswood.

Natives themselves are confused when asked to classify False Faces. One old Seneca informant, Henry Red-Eye, told me there are as many False Face types as there are different people. Some are portraits of youths; others are of old men who have long, white hair and wrinkled faces. There are angry individuals with broken noses and mouths skewed to one side as if they had suffered paralytic strokes who are apt to sweat and cause an owner illness, if he neglects to supplicate them with tobacco offerings. Some have distended, open lips as if they were blowing ashes; a few with standing hair and raised eyebrows are whistling and merely want tobacco, while others protrude red tongues or laugh, revealing irregular rows of wooden or

bone teeth. Their similarities are only those which the culture has prescribed in dreams.

Tradition has dictated the forms which the faces assume in visions, and the features which the craftsmen emphasize when carving, the very features which the Indians mention when describing the original forest folk. It is sufficient for the carver to single out particular features of the face for artistic expression; the face portrays the being, and the wearer must dramatize his other attributes: his erect or slouching gait, his awful mien and the nonsensical, nasal speech which he accompanies by shaking a rattle. To the Indians, the total effect is both terrifying and extremely humorous. In general, the masks have deep-set eyes, rendered bright by metal sconces, and large, frequently bent noses. The arched brows are deeply wrinkled and divided above the nose by a longitudinal crease or a comb of spines, which one Seneca calls "Turtle-tail," because they resemble the processes on a mud-turtle's tail. Thick, distended lips protrude beyond the nose, and a series of modifying wrinkles augment the distorted expression. Cheek bones are sometimes suggested, and a prominent chin, common on masks from Grand River, serves as a convenient grip for the wearer to adjust the mask to his face. The face is framed by a long wig, usually cut from black horsetails which fall on either side from a part in the middle of the forehead; but anciently, corn-husk braids or buffalo mane served as hair. Masks are commonly painted red or black.



Buffalo Museum of Science.

ANCIENT IROQUOIS MASKS FOR BEGGING TOBACCO, PROBABLY SENECA.

IROQUOIS HUNTERS MET THESE QUASI-HUMAN BEINGS IN THE FORESTS, DREAMED OF THEM AFTERWARD AND CARVED THEIR FACES ON LIVING TREES. THE FROWNING FACE, WERE IT ADORNED WITH LONG HAIR, MIGHT APPEAR AS A DOOR-KEEPER AT A CURING RITUAL. THE SECOND IS A MERRY BEGGAR, AND THE THIRD IS WHISTLING; THEY MERELY WANT TOBACCO.

Collection of the Onondaga Historical Society.

NINETEENTH CENTURY ONONDAGA MASKS.

DeCost Smith, the artist, while on a visit to Onondaga Castle in the eighties, discovered masks in an Indian's garret, collected them for his friend, the Rev. Wm. M. Beauchamp, and learned that the masked societies were still active.

Narratives of Early Travelers

Although the Iroquois have felt three centuries of white contact, the earliest travelers mention masks and describe masked ceremonies which suggest modern rituals. The Jesuits wrote home accounts of face painting and masking, comparing the Indians with the masqueraders of provincial France. The author of Van Curler's journal, who visited the Mohawks and Oneidas about 1635, tells us that a chief showed him his idol, which was a head with teeth sticking out, and that he kept it draped in a red cloth. This is reminiscent of the modern custom of covering masks when putting them away. The "Relation" for 1637 describes the False Faces and their Husk Face doorkeepers among the Hurons. In a dance to drive away pestilence, "all the dancers were counterfeits of hunchbacks, with wooden masks the whole ridiculously made, and each a staff in hand; behold an excellent medicine. At the end of the dance, at the order of the sorcerer *Tsondacoüané*,[1] all the masks were hung at the top of a pole at the top of each cabin, with the straw men at the doors." The next night they hung "the wooden masks and strawmen above each cabin." At another time, they put "a sack on the head, pierced only at the eyes."[2]

The latter may be "Longnose," the

[1] godi̯čoni—she sponsored the ritual.

sadi̯čoni—you sponsored the ritual > you sponsor.

[2] Citations from William M. Beauchamp, New York State Museum, *Bulletin* 89, p. 184, New York State Education Department, Albany, 1905.

Kidnapper. The Jesuits, Dablon and Chaumonot, who witnessed the mid-winter festival at Onondaga during 1656, do not mention masks but describe their host, covering himself with corn husks from head to foot, who went accompanied by two women with blackened faces and bodies covered with two wolf skins. Each woman carried a club or a great stake.[3] Beschefer, who accompanied De Nonville's expedition to the Seneca, wrote in the "Relation" of 1687 to Villermont:

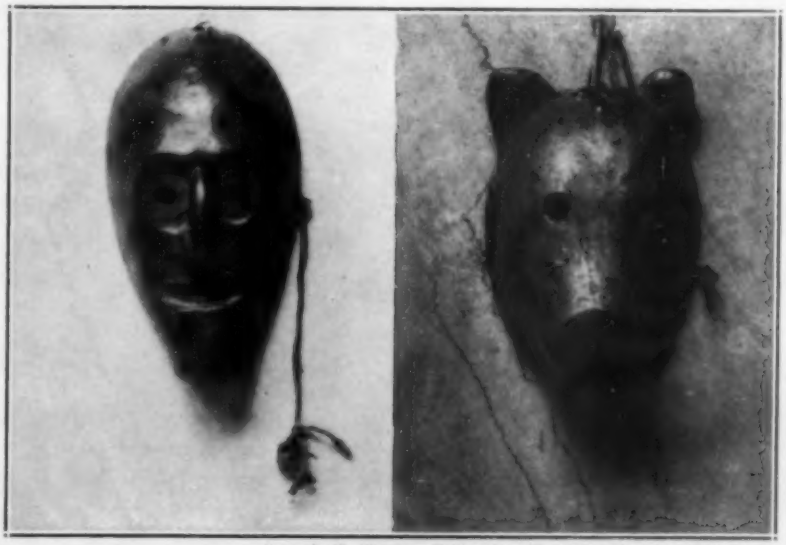
> I was mistaken when I told you that the Iroquois wore no masks. They make some very hideous ones with pieces of wood, which they carve according to their fancy. When our people burned the villages of the Tsonnontouans (Seneca), a young man made every effort in his power to get one that an Outaouae (Ottawa) had found in a cabin, but the latter would not part with it. It was a foot and a half long, and wide in proportion. Two pieces of a kettle, very neatly fitted to it and pierced with a small hole in the center, represented the eyes.[4]

Beauchamp holds that since the Seneca had one Huron town after 1648 that the Huron may have introduced the False Face Society to the Seneca, from whence it spread through the other nations of the Confederacy. Lafitau, who bolstered his own observation with the earlier "Jesuit Relations," mentions masks made from the bark of trees in his "Customs of the American Savages."[5] John Bartram, the Philadelphia naturalist, recorded an unmistakable description of a False Face

[3] "Jesuit Relations," Vol. 42, p. 154 (Thwaites edition).

[4] Beauchamp, *op. cit.*, p. 184.

[5] P. F. Lafitau, "Moeurs des Sauvages Amériquains," 2 vols. Paris, 1724, Vol. I, p. 368.



Joseph C. Greene Collection, Buffalo Historical Society.

THE CLASS OF BEGGAR MASKS IS MOST PLASTIC.

(*Left*). MASKS MORE NEARLY RESEMBLING HUMANS, LIKE THIS ONE FROM CHIEF ELY S. PARKER, U. S. A., WHICH HAD ITS FACE DECORATED WITH TRIANGLES AND CRESCENTS (ILLUSTRATION DOES NOT REVEAL THE PECULIAR FACE PAINTING) FOR SOME OCCASION, AND WEARS A TOBACCO OFFERING TO ATTEST ITS CURING POWER, HAVE GONE OUT OF USE AT TONAWANDA.

(*Right*). WITH THE DISAPPEARANCE OF THE BEAR, THE PIG HAS BECOME THE PRINCIPAL FEAST ANIMAL AMONG THE REMNANT IROQUOIS, AND THE PIGHEAD HAS ACQUIRED A REFLECTED HOLINESS BY ASSOCIATION WITH THE RITUALS OF MEDICINE SOCIETIES. THE PIG MASK, PERHAPS DERIVED FROM MASKS REPRESENTING THE BEAR, HAS NO SPECIAL FUNCTION AMONG THE SENECA.

beggar who kept him awake at Onondaga in 1743.

> We were entertained by a comical fellow, disguised in as odd a dress as *Indian* folly could invent; he had on a clumsy vizard of wood colour'd black, with a nose 4 or 5 inches long, a grinning mouth set awry, furnish'd with long teeth, round the eyes circles of bright brass, surrounded by a larger circle of white paint, from his forehead hung long tresses of buffaloes hair, and from the catch part of his head ropes made of the plaited husks of *Indian* corn; I can not recollect the whole of his dress, but that it was equally uncouth; he carried in one hand a long staff, in the other a calabash with small stones in it, for a rattle, and this he rubbed up and down his staff; he would sometimes hold up his head and make a hideous noise like the braying of an ass; . . . In my whim I saw a vizard of this kind hang by the side of one of their cabins to another town.[6]

Probably a custom as wide-spread over the world as dressing in masks to impersonate other beings permits us to assume that the Iroquoian custom of wearing False Faces sprang from their own culture, where it became so firmly imbedded that, despite three hundred years of buffeting by white contact, the masks have maintained standards prescribed in the original legends. The masks show little fundamental change from generation to generation, except that they become increasingly ornate or grotesque when influenced by the adoption of better tools or the degeneration of the wood carver's art; and masks portraying a pig, the Devil, and such amusing figures as Mickey Mouse, Felix Cat and Charlie Chaplin have encroached only on the group of faces designed to elicit laughter—the class of beggar masks—which is the most plastic.

The Husk Faces

Besides the wooden False Faces, cornhusk masks and buckskin or cloth masks represent two other classes of beings. The technique of twining and braiding corn husks in the manufacture of shoes, mats and dishes is ancient among the Iroquois peoples. Nevertheless, the Husk Face Society is probably no older than sewing braided corn husks for seats and foot-mats, since the Husk Faces and the beings which they represent are named for the mats (gadjí'sa'). A person awaking with his hair standing awry, like the pile of a foot mat, is said to look like gadjí'sa'. The Husk Faces look like door-mats, the only difference being that the masks have holes for the eyes and mouth. The Husk Faces are a race of agriculturists. They dwell on the other side of the earth in a ravine where they till their fields amid high stumps. Coming from the East every new year, they visit the Seneca longhouses during two nights of the mid-winter festival. Preceded by runners, they finally arrive amid a great din of beating the building with staves, stop the dances and kidnap a chief for interpreter. As messengers of the three sisters—corn, beans and squash—our life supporters, they have great powers of prophecy. The interpreter relates the message of the old woman, their leader, that they are hurrying westward to hoe their crops. In fields about their houses they grow huge squashes; the corn has giant ears and string-beans climb up poles to heaven. Some of their women have remained home to tend to crying babies. Recently in their country there is employment on public works projects. These statements are accepted as an augury of fertility. They request the privilege of dancing with the people. All their company are men, but some dress as women and participate in the dances as if they were women.

The Husk Face Society is by no means as well integrated or prominent as the False Face Society, although they share certain functions. Unlike the False Faces, they are mutes and only puff as

[6] John Bartram, "Observations on the Inhabitants, Climate, Soil, Rivers, Productions, Animals . . . in Travels from Pennsilvania (sic) to Onondaga, Oswego and Lake Ontario." London, 1751 (reprinted at Geneva, N. Y., 1895), p. 43.

Fenton Collection.

THE HUSK FACES REPRESENT A FARMING PEOPLE.

THE FACES OF THE BEINGS WHICH THE HUSK FACES REPRESENT ARE SAID TO LOOK LIKE FOOT-MATS OF BRAIDED CORN HUSKS. IN THE DEAD OF WINTER, A COMPANY OF MASQUERADED MEN AND BOYS DRAMATIZE THEIR VISIT TO THE LONGHOUSE TO FORECAST BOUNTIFUL CROPS AND THE BIRTH OF CHILDREN DURING THE FOLLOWING YEAR. INFORMANTS RECOGNIZE THESE MASKS FROM COLDSPRING AS AN OLD GRANDFATHER (*left*), A GRANDMOTHER (*middle*), AND A YOUNG WOMAN (*right*), SINCE IT HAS LONGER HAIR AND THE TWINING TECHNIQUE IS FREE OF WRINKLES.

THE HUSK FACES LINGER AND DANCE WITH THE LONGHOUSE PEOPLE.

(*Left*). A SENECA PAINTS A SPOT OF RED ON EACH CHEEK WHEN GOING TO A FESTIVAL AT THE LONGHOUSE. THIS TWINED HUSK MASK BELONGS TO THE GREAT PUBLIC RITUALS OF THE HUSK FACE SOCIETY AT COLDSPRING LONGHOUSE. (*Middle*). AT CATTARAUGUS, THE MASKS OF FINE BRAID WITH BUNDLES HUNG ON THEIR CHEEKS REPRESENT FEMALES (PEABODY MUSEUM, YALE UNIVERSITY). (*Right*). THE ROUGH TWINING SUGGESTS AN OLD MAN.

they run with great leaps. They have their own tobacco invocation, a medicine song, and dance about the staves which they carry. They also have the power to cure by blowing hot ashes; but in Canada, they sprinkle water on their patients. They like tobacco, but they prefer popcorn at Allegany and dumplings at Newtown and Tonawanda, instead of mush. When four suddenly appear racing between the houses, they may be signalling the approach of the False Face Company. They will loiter, policing the premises until the Common Faces depart. Relatively few Indians belong to their society, and set a kettle down for them to renew an old dream, but many put on their masks for the public longhouse rituals, and others join them in social dances at the end of the line.[7]

Buffalo Museum of Science.

AN OLD TYPE OF FACE WHICH APPEARS AT COLDSPRING AND GRAND RIVER.

LONGNOSE, WHO KIDNAPS NAUGHTY CHILDREN

The Iroquois and their Algonquin neighbors use buckskin masks to impersonate cannibal clowns who sometimes kidnap naughty children. The Seneca call this clown "Longnose" (hagónde·s) because of his elongated proboscis. He is the Indian bogey-man. He chases bad children when the old people are sleeping. He mimics them, crying out as he runs after them. But the old folks do not wake up, since he has bewitched them in order that they will remain sleeping. This goes on all night until the child gives up and agrees to behave, or else Longnose makes away with the child, carrying him off in a huge pack-basket. It is not right to whip little children. Stubborn children who will not go to bed are sometimes sent out at dusk to meet Longnose, impersonated by a relative wearing a cloth mask. The child immediately runs into the house. Neither is it right to use the great wooden masks belonging to the medicine society for scaring little children. The great Faces are sacred and should not be ridiculed; and the being they represent might, through the mask, "poison" the child, or "spoil his face" and bring bad luck to the wearer.

THE BIGHEADS

At the mid-winter festival, two women dress two men in buffalo robes, which they bind with ropes of braided corn husks,[8] from which the ears have been successively pulled for consumption; they hand the men wooden corn-pounders and dispatch them about the village. These heralds impersonate the "Uncles" or "Bigheads" who run through the fires

[7] Arthur C. Parker, "Secret Medicine Societies of the Seneca," 1909. Reprinted in New York State Museum, *Museum Bulletin* 163. Albany, 1913, p. 129.

[8] Two men dress them at Newtown.

heralding the Feast of Dreams which marks the new year. Their costume symbolizes the union of trophies of the hunt and fruit of the harvest. The Bigheads should not be confused with the wooden False Faces or the Husk Faces, who form two distinct but somewhat linked medicine companies.

The Origin of False Faces

Among the Seneca there are two prevailing types of origin legends for the wooden False Faces. One is a mythical epic belonging to the creation; the other is a human adventure. Both are associated with different classes of beings. In abridged form, here is what Chauncey Johnny-John and Henry Red-Eye heard from their "old folks."

The Struggle for Control of the Earth

Now when our maker was finishing this earth, he went walking around inspecting it and banishing all evil spirits from his premises. He divested the Stone-coats and banished them as harmful to men. He removed the Little Folk's stone shirts and permitted them to remain to help hunters and cure illness. As the creator went on his way westward, on the rim of the world, he met a huge fellow—the head man of all the Faces. The creator asked the stranger, as he had asked the others, whence he came. The stranger replied that he came from the Rocky mountains to the west and that he had been living on this earth since he made it. They argued as to whose earth they traversed and agreed to settle the title by contest. The Creator agreed to call the stranger "headman," should he demonstrate sufficient magic strength to summon a distant mountain toward them. They sat down facing the east with their backs to the west and held their breaths. Now the great False Face shook his giant turtle rattle and the uproar frightened the game animals. He summoned the mountain toward them, but it moved only part way. Now it was the Creator's turn, and he summoned the mountain, which came directly up to them. However, his rival, becoming impatient, suddenly looked around, and the mountain struck his face. The impact broke his nose bridge, and pain distorted his mouth. Now the Creator realized that this fellow had great power. He assigned him the task of driving disease from the earth and assisting the people who were about to travel to and fro hunting. The loser agreed that if humans make portrait masks of him, call him grandfather, make tobacco offerings, and set down a kettle of mush, that they too shall have the power to cure disease by blowing hot ashes. The Creator gave him a place to dwell in the rocky hills to the west near the rim of the earth, and he agreed to come in whichever direction the people summon him.

Fenton Collection.

THE MASK OF LONGNOSE WHO KIDNAPS NAUGHTY CHILDREN.

The Good Hunter's Adventure

Later, as humans went about the earth, in the fall men went into the woods hunting. They carried native tobacco and parched corn meal for mush. They were tormented by shy, querulous beings who flitted timidly behind trees with their long hair snapping in the wind. Sometimes, a hunter returned to his camp to find the ashes of his fire strewn about the hearth and the marks of some great, dirty hand where someone had grasped a house post for support as he leaned over and pawed in the fire. The hunter agreed to stay home while his partner went afield. During the morning, a False Face approached cautiously, sledging on one hip, now and then standing erect to gaze about before

proceeding. Going to the hearth, he reached into the ashes and scattered the coals as if seeking something. That night the hunter had a dream in which the False Face requested tobacco and mush. The next day, the hunter set a kettle down for them. The Faces came and taught him their songs and their method of treating patients with hot ashes. In a subsequent dream, they requested him to remember them every year with a feast, saying they are everywhere in the forests, bringing luck to those who remember them.

Another legend from Chauncey Johnny-John tells of a hunter who inadvisedly shot, but failed to kill an old man whom he discovered seated on a log in the forest. The man returned the arrow, instructed the hunter to make one hundred bark bowls, to cook a great kettle of mush, and provide tobacco for a company of one hundred who would appear next day. The surprised hunter fulfilled everything, and when he was ready, Faces of all ages gathered around his fire. The old man, who was their leader, taught him a tobacco invocation and three songs. They showed him how to cure by blowing hot ashes, and presented him with a miniature mask to serve as a model for making larger ones.

Hunters returned home to their villages. They related their strange adventures and revealed their dreams. Sometimes after returning home, they had new dreams and received further instructions. They showed their people how to make masks and they organized a medicine company.

The Classes of Medicine Masks

Rationalizing from the two types of origin legends, the modern Seneca conceive two main classes of False Faces: first, their leader, the great fellow who lived on the rim of the earth, and secondly, his underlings, the common forest people whose faces are against the trees. The great one, called shagodjowéhgo' wa·², is the greatest doctor. He is earth bound and traverses the earth from east to west following the path of the sun. He is tall and carries a great staff, made from a giant pine or shag-bark hickory tree with its branches lopped off to the top. He walks with great strides, bumping his cane and shaking the earth. He carries a huge mud-turtle rattle, and he

OUR UNCLES, THE BIGHEADS.

At the Midwinter Festival, two men are appointed, one from each group of four clans, to impersonate the Bigheads who make three excursions from house to house announcing the New Year ceremonies. Their buffalo robes represent hunting, the corn husk braids symbolize agriculture, and the striped corn pounders signify the return to sedentary village life.

stops at noon to rest and rub his rattle on the giant elm or pine which stand in the center of the earth and from which he derives great strength. His face is red in the morning as he comes from the east, but black in the afternoon as he looks back from the direction of the setting sun. He controls high winds and has a wary eye for pestilences which might destroy the people. He has a song which refers to his power over winds and pestilence. Few have ever seen him. He dances, kicking out his feet and sparring, his thumbs pointed in the air as if he were about to fall over backward. He makes the people imitate him, organizes them in a round dance, and watches the door to see that no one leaves or enters. Masks representing him have long hair. They are painted red or black and portray the broken nose and pain he suffered when the mountain struck his face. A few masks have high bridged noses, and all have protruding lips, which are either distended like two funnels or flattened like two spoons, for blowing ashes.

The second class are the Common Faces, who live everywhere in the forests. They are deformed, either hunchbacked or crippled below the waist. Some carry rattles, made by folding a rind of hickory bark; a few possess turtle rattles, but others have only a stick. They crave mush and beg for tobacco. They have a dance and a song, and they will cure by blowing hot ashes. Masks of this category are ill defined and include a great variety. Frequently new masks make their *début* with the Common Faces; but after they have been worn in many rituals, borrowed and passed through the hands of several owners, they will have accumulated several bags of tobacco offerings, attained an antique color, and achieved sufficient prestige to graduate into the class of great doctor masks where their sanctity is preserved by reputation.

Three Societies Employ Masks

Among the Seneca, three distinct medicine societies employ masks. They perform their rituals in public or privately. The False Face Company, who wear the wooden masks, include both the orders of medicine masks who have three distinct rituals. Their public rituals are the spring and autumn exorcism of disease from the settlements and cures which are sometimes sponsored in the longhouse

OUR MIGHTY PROTECTOR TRAVERSES THE EARTH.

An Allegheny Seneca employs a blanket as a headthrow, wears his father's mask and carries a turtle rattle to impersonate Shagodjowéhgo·wa·' whose heavy tread shakes the earth.

during the mid-winter festival. However, the public appearance of the Beggars and Thieves, during several nights of the mid-winter ceremonies, are merely a motley group of boys who sometimes "take sick" afterward and thereby gain admittance to the society. The second ritual belongs to the Common Faces, who enter a house and dance. The Common Faces may be followed by the great, world rim Faces, whose ritual is the Door-keeper's Dance. The Society of Faces is the body of people who have been cured by the masked company. The separate society of Husk Faces appears publicly two nights at the mid-winter festival. They have their own invocations, songs and a curing dance. Membership is gained by a dream or cure, but non-members join in their public dances, dancing at the end of the line.[9] Frequently, at Allegany two special Husk Faces appear as door-keepers for the Common Faces at private curing rites and as heralds and longhouse police during public rituals. Among the Canadian Iroquois, masked societies seem more highly specialized, but at Allegany and Tonawanda their functions are less clearly defined. At Newtown, on Cattaraugus reserve, the Society of Mystic Animale (hadi'do's) possess certain "secret masks" of which one has no eye holes, but at Coldspring on Allegany Reservation certain black or white Faces, which are also used as medicine masks by the Society of Faces, appear in one ritual of the Society of Mystic Animals and juggle hot stones or hot ashes while curing the patient.

Membership

A Seneca Indian joins a particular medicine society after a dream or following a sickness because a clairvoyant has prescribed the ritual of that society for his cure. He automatically joins all the societies, and is afterward duty bound to sponsor any combination of rituals that have assisted his recovery. Thus the Society of Faces includes those who have been cured by the False Face Company. Membership in the several orders of the society, or participation in the rituals of the masked company depend on the individual's personal history. The masked company are men wearing masks of the orders which cured them, but both men and women sponsor the rituals and belong to the orders who have accepted them for membership in the society by making them sick. Two head women, one from each moiety of four clans, are responsible for certain equipment and manage the rituals. Members of both sexes attend. A member should put up a feast every year for the orders which have helped him. He calls in the head woman of the opposite moiety to conduct the ritual. His membership ceases rarely, when he dreams he has been outcast. Then he knows he is no longer a member.

The False Face Sickness

Symptoms of the False Face sickness are ailments of the head, shoulders and joints. They cause and cure swelling of the face, toothache, inflammation of the eyes, nose bleeding, sore chin and earache.[10] At Tonawanda, red spots on the patient's face are False Face symptoms. This calls for the red Faces, who should dance in the morning before sunrise. Black spots require the use of black masks at night. Imaginary hair, lying on the patient's face, indicated by her attempts to brush it aside, is a False Face symptom. The patient complains to her old people. They consult a clairvoyant, who prescribes a False Face ceremony.

[9] A. C. Parker, "Secret Medicine Societies of the Seneca," 1909. Reprinted in New York State Museum, *Museum Bulletin* 163. Albany, 1913, p. 129.

[10] A. A. Goldenweiser, "Field Notes circa 1912." Vol. 12, p. 41; Lewis H. Morgan, "League of the Iroquois," Vol. I, pp. 157–160. N. Y., 1901.

THE DOORKEEPER.

SHAGODJOWÉHGO·WA·' PERMITS NO ONE TO ENTER OR LEAVE DURING HIS RITUAL. THE MASK, FROM CATTARAUGUS RESERVATION, IS THE PROPERTY OF THE ROCHESTER MUSEUM OF ARTS AND SCIENCES.

To ridicule the masks or any of their ceremonies is inviting sickness or misfortune.

A peculiar form of hysterical possession formerly occurred among women at Tonawanda. An informant states that it was confined to certain nervous women who became possessed of the False Face spirits whenever the masked men appeared.[11] On hearing the rumpus of whining and rattles, which marks their approach, one woman would fall into spasms, imitate their cry and crawl toward the fire, and, unless she was restrained, plunge her hands into the glowing embers and scatter the fire as if she were a False Face hunting tobacco. Some one always grabbed her, while another burnt tobacco, imploring the masked men to cure her. The ritual usually restored her normal composure. Other women became possessed of the tutelaries of the Bear or Buffalo societies. My informant used to think women became possessed to show off. Some of these women were clairvoyants. Another informant remembers a man who became possessed,[12] thirty years ago at Newtown, for resisting a Door-keeper. When the masked ritual conductor nudged him with his rattle, he obstinately refused to join the round dance. They struggled

[11] Peter W. Doctor.

[12] Jesse J. Cornplanter.

Fenton Collection.

CARVING HAS IMPROVED WITH NEW TOOLS.

(*Left*). AN UNFINISHED BLACK DOOR-KEEPER MASK BY CLARENCE WHITE OF COLDSPRING, 1923. LACKING LONG HAIR, THIS FACE MIGHT APPEAR AS A BEGGAR. (*Right*). THE WHISTLING FACE, A BEGGAR, THAT SUGGESTE A MASK IN USE AMONG THE DELAWARE. THE TOBACCO BAGS AT THE FOREHEAD ATTEST ITS LONG USE.

Fenton Collection.

DOOR-KEEPER MASKS ARE RED OR BLACK.

(*Left*). AMOS SNOW'S MASK, PERIOD OF ABOUT 1850, PORTRAYS "THE BROKEN NOSE AND THE CROOKED MOUTH WHERE THE MOUNTAIN STRUCK HIS FACE." (*Right*). JONAS SNOW'S MASK, MADE ABOUT 1924 AT COLDSPRING, IS A FINE EXAMPLE OF MODERN CARVING AND THE DOOR-KEEPER FACE WITH PROTRUDING LIPS.

and the man, overcome with fear, fell into a spasm and cried like a False Face. They had to blow ashes on him. Afterward, the man did not remember his behavior. In all cases, the form of the hysteria was prescribed by the culture.[13]

THE MASK AND RATTLE

Men belonging to the Society of Faces usually own a bundle containing a turtle rattle and one or more masks decorated with bags of sacred tobacco. When not being used, the mask is laid away, face down with its hair wreathed around the face and the turtle shell placed in the hollow at the back of the mask; and the whole is wrapped in the cloth head cover. Sometimes, unwrapped masks are hung upstairs, but facing the wall. A mask hung facing out should be covered, lest some frightened persons become possessed and join the society. One must be careful of them. If a mask falls, the owner burns a tobacco offering and ties a little bundle of sacred tobacco at the ear or forehead. Whenever he dreams about the Face, he will rise and repeat the ritual. Every man has a package of

[13] The Feast of Fools, described by the Jesuits, has evolved from a random series of hysterical dream fulfilments to an organized midwinter festival by a gradual standardization of forms differing according to locality.

A MEDICINE MASK AT COLDSPRING.

THIS BEGGAR MASK HAS, THROUGH LONG ASSOCIATION WITH CURING, ACCUMULATED SEVERAL BUNDLES OF SACRED TOBACCO AND NOW BELONGS TO THE CLASS OF DOCTOR MASKS.

tobacco on his mask which he removes when he sells it to white people. He burns tobacco, telling the mask that it is going away. He asks it not to return and harm him or the new owner. Everyone belonging to the society may use any one else's face. A new owner will add a package of tobacco to a mask, and if he purchases one already having several medicine bundles attached, he adds his own; but a maker does not tie tobacco on a mask unless he intends to keep and use it. Sometimes the masks become hungry and the owners rub their lips with mush and anoint their faces with sunflower oil, which after many years imparts a rich luster. A man, having no children, may request that a mask be buried with him.

Unless the new member inherits an old mask, he must carve one or enlist the services of a carver. They say at Tonawanda that "Softer woods are best for carving masks. Basswood has the prestige of tradition, but other soft woods like willow and cucumber . . . are also used. Anciently, a man went into the forest to carve his masks. He carried native tobacco and sought a living basswood tree. Now he committed the tobacco to the burning embers, a pinch at a time, addressing his prayer to the tree and the beings whom the False Faces represent. Then he carved the face on the living tree, and having roughed it out, he notched the tree with an axe above the forehead and below the chin and cleaved away his sculpture in a solid block. It is said that the carving never broke because one had put tobacco and asked the tree for its life. Nor did the tree die. Within four years, the scar healed over. He took home his block, covered it and worked on it at his leisure. When the features were finished, he hollowed out the inside (with a bent, farrier's knife), and perforated the eyes, nose and mouth. He encircled the eyes with metal, for the Great False Face's eyes are bright. Then he painted it. If he had sought his tree in the morning, he painted the mask red; but if he found the tree and commenced carving after noon, the mask would be black."[14] This color symbolism originates with the theory of morning and afternoon appearance of the giant, world rim resident. During his daily, westward journey following the path of the sun, his

[14] Cephas Hill and William N. Fenton, "Reviving Indian Arts Among the Senecas," "Indians at Work," Vol. II, Number 21, pp. 13–15. Office of Indian Affairs, Washington, D. C., June 15, 1935, p. 14.

face would appear red in the morning and dark in the afternoon when the sun is behind him. For the long hair which falls on either side to his knees, the mask-maker attaches to the forehead horsetails, tanned with deer brains.

Ritual Equipment

The False Face Company carry wooden staves and employ three instruments: the typical mud-turtle rattle, a folded bark rattle or a billet of wood. On late spring evenings, before summer heat peels the turtle's shell, Indians watch for turtles about the ponds and creeks. In the evening one may meet an Indian bearing a burlap sack containing a turtle, or he carries it by the tail; he is bound to the house of a friend who "can fix it" for a rattle. The rattle maker cuts off the turtle's tail or severs the jugular vein and hangs it to drain. Later, he eviscerates and cures it. He sews up the apertures left by removing the rear limbs and inserts a handful of cherry pits. He stretches the neck over a pine stick which extends from inside the shell to the base of the skull where it is notched. He sews the front rents. Cutting three hickory splints, he inserts one in the sternum, cutting it off under the jaw, and he inserts two lateral splints in the back of the shell, terminating them on top of the head. He binds the splints to the neck with basswood fiber, a withe of inner elm bark, or rawhide, commencing at the shell and whipping toward the head. A ten-inch rattle is best for singing, but the mammoth turtle rattles lend awe to the door-keepers at curing rites and small turtle rattles furnish comedy for little boys playing beggars.

For the bark rattles, a cylinder of

Fenton Collection.

A MEDICINE FACE FROM GRAND RIVER.

CANADIAN MASKS ARE MASSIVE AND HEAVY AND LONGER THAN THE AVERAGE HUMAN FACE. A COLDSPRING SENECA BOUGHT THIS MASK OF A GRAND RIVER SENECA AND BROUGHT IT HOME.

Buffalo Historical Society.

SPOON-LIPPED DOOR-KEEPER MASK.

THE SPOON-LIPPED DOOR-KEEPER IS CHARACTERISTIC OF CATTARAUGUS. THE MASK ILLUSTRATED HAS EARS PERFORATED FOR EARRINGS, SILVER EYES AND THE RIDGE OF SPINES ABOVE THE NOSE CALLED "TURTLE-TAIL."

Fenton Collection.

THE COMMON FACES INCLUDE A GREAT VARIETY.

(*Upper left*). This mask, which Chauncey Johnny John made about 1900 for his wife's brother, has gone through many curing rituals. (*Upper right*). Beggar masks usually have standing hair, but this one also has a beard and a broken nose like the ancient World-rim-dweller. (*Lower left*). A Happy Face, a Beggar mask made at Coldspring about 1920, credited with great healing power. (*Lower right*). The Chinaman Beggar mask.

green hickory bark is slit longitudinally and peeled around the tree. The maker spreads it at the middle by inserting his thumbs and folds it end to end, placing one curled end inside the other. A few cherry pits, pebbles or kernels of corn provide the necessary percussion. He plugs the open end with a corn cob and lashes it with a bark withe. A man will make a dozen on a summer afternoon and toss them overhead in the loft to dry.

At next mid-winter festival, a band of outlandishly dressed little boys wearing beggar masks may visit him soliciting or pilfering food and tobacco for a feast. He will reward them, and then, reaching overhead, distribute his rattles to those poor youngsters who were unable to locate turtle rattles and carry sticks of kindling. Perhaps he has no children of his own. He will sing for them and they will dance and depart.

A rattle borrowed from a dancer or a stick of wood is good enough to beat time for the dances. But despite the Indians' ingenuity to make shift of anything at hand, the False Face Company sometimes possess dance-tempo beaters. They range in design from wooden cudgels to elaborately carved wooden turtles that have been hollowed to house noisy pebbles. These wooden replicas of the genuine turtle rattles exemplify the transfer to an artistic medium of a design originating with a structural invention.

Miniature Masks

Boys sometimes learn by carving miniature masks. The mask may make the owner ill and then he joins the society. Masquettes are also charms to protect dwellings against witchcraft, or they hang on larger masks. A man may carve one in response to a dream and carry it for good luck. At Cattaraugus, the matron of the society carries a striped pole on which a tobacco basket, a small wooden face, a tiny Husk Face and a diminutive mud-turtle-rattle hang near the top. This is her staff of office when she leads the masked company from house to house exorcising plagues.

Spring and Autumn House Cleaning

In the spring and fall, when sickness lingers in the settlements, a great company, wearing both classes of medicine masks, go through the houses frightening disease spirits. At Coldspring, two groups start at opposite sides of the settlement. They are preceded by Husk Face runners. Members take down their masks and rattles and join the procession as it passes. The masked exter-

Rochester Museum of Arts and Sciences.

THE CARVER.

The Carver, Harrison Ground of Tonawanda, outlines the features of the face before hollowing the back of the mask.

THE COMMON FACES OF THE FORESTS ARE CRIPPLES.

MASKS OF THE DOORKEEPER TYPE FREQUENTLY APPEAR TOGETHER WITH THE COMMON FACES, AND SINCE THE RITUAL PRESCRIBES A CRAWLING POSTURE FOR COMMON FACES AND ERECT STATURE FOR DOORKEEPERS, THE BEARING AND GESTURES OF THE ACTOR ARE MORE IMPORTANT THAN THE TYPE OF MASK HE WEARS.

Rochester Museum of Arts and Sciences.

CROOKED FACE ENTERS CRAWLING LOOKING FOR TOBACCO.

THIS BEGGAR MASK, WORN BY DENISON MOSES, WAS CARVED BY ELON WEBSTER OF TONAWANDA ON A WPA INDIAN ARTS AND CRAFTS PROJECT SPONSORED BY THE ROCHESTER MUSEUM OF ARTS AND SCIENCES. THE MOCCASINS REPRESENT A WESTERN BORROWING.

minators frequently strip to the waist and go armed with rattles to scare the spirit of sickness and carry pine boughs to brush away malefic influences. A believer is said to suffer no injury from plunging his bare hands into the fire nor become sick from exposure while traveling in cold weather. One winter at Allegany the company afforded a wild spectacle as they sped up the valley road in open Fords with their hair whipping in the chill winds; they grated their rattles on the car body and uttered their terrifying cries whenever they swerved to pass a stranger. Approaching houses occupied by members of the society, an unmasked leader sings:

A long voice, A long voice
yowige yowige wige

and again on entering the longhouse:

It might happen, It might happen
ha i ge ha i
From the mighty Shagodjoweh
ha i ge he i
I shall derive good luck
ha i ge he i.

He hopes that the great one dwelling on the rim of the earth will confer his power on the masked company and prevent high winds from leveling the settlement. They scour the exterior of the house and, crawling through the door, visit every room. They sweep beneath the beds and peer into every nook and corner for disease spirits. They haul the sick out of bed and sometimes commit indignities on lazy people. If some one has set a kettle down for them, their leader will burn tobacco, and ask the masked company to blow ashes on the patient. Their only fee is native tobacco, which their guide collects in a twined, husk basket. Once at Newtown, a leader was about to gather his company of exterminators and depart for another house when one turned up missing. They heard a most terrifying racket in the loft. They ascended to discover him violently shaking an old straw bed tick-

ing, from which bedbugs were fleeing by the score. This fellow, now an old man, possessed of an extraordinary sense of the ridiculous, was shaking his rattle and crying in the most orthodox manner. It is a good example of the frivolity which may pervade an otherwise serious ritual.

Meanwhile, the two matrons brew a purgative at the village cook-house. At Newtown and Tonawanda, the sole ingredient is parched, white sunflower seeds, which are steeped for the medicine, but at Allegany they add "man-root" (*Ipomoea pandurata*), which must be found growing erect like a living person.

The community assembles at the long-house. An appointed speaker returns thanks to all the spirit-forces. At Coldspring, Husk Face runners and the marching song signify the approach of the combined company. Bursting into the room, the False Faces crawl toward the fire. Each matron entrusts a pail of medicine to one of them whom she designates "water waiter" for her moiety. Lest they scatter the fire about the room, an appointed priest makes an invocation, burning the tobacco that was levied at the houses. He implores them to protect the people against epidemics and tornadoes.

TOBACCO INVOCATION

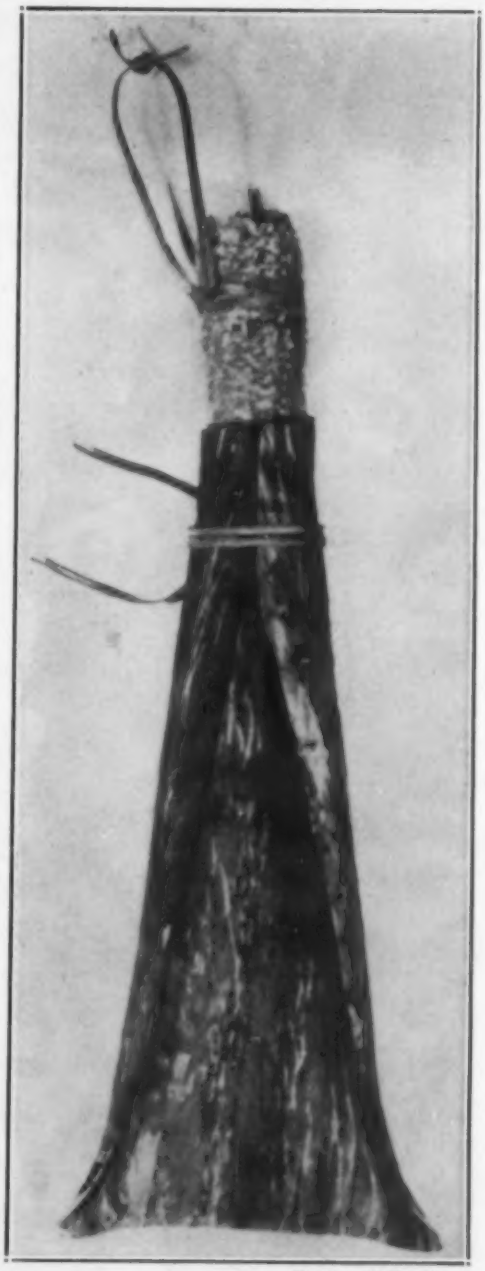
Partake of this sacred tobacco, O mighty shagodjoweh, you who live at the rim of the earth, who stand towering, you who travel everywhere on the earth caring for the people.

And you too, whose faces are against the trees in the forests, whom we call the company of faces; You also receive tobacco.

And you Husk Faces partake of the tobacco. For you have been continually associated with the False Faces. You too have done your duty.

Partake of this tobacco together. Every one here believes that you have chosen him for your society.

So now your mud-turtle rattle receives tobacco. (Here they scrape their rattles on the floor).



Fenton Collection.

A FOLDED HICKORY BARK RATTLE.

So now then another thing merits tobacco, the very place where you rub your rattle, the giant elm tree standing on the center of the earth. (Again they approve.)

MAKING A TURTLE RATTLE.

JONAS SNOW BINDS THREE HICKORY SPLINTS TO THE TURTLE'S NECK WITH RAWHIDE LASHING.

And now another thing receives tobacco, your staff, a tall pine with the branches lopped off to the top.

So presently you will stand up (they crawl in) and help your grandchildren, since they have fulfilled your desires. Fittingly, they have set down a full kettle of mush for you. It is greased with bear fat. Now another thing is fulfilled: on top there are strips of fried meat as large as your feet. (Here the False Faces roll in ecstasy on their backs, grasping their feet, peering at them, and attempting to put them in their mouths). Besides, a brimming kettle of hulled corn soup rests here.

Now it is up to you. Arise and help your grandchildren. They have fulfilled everything that you requested should be done here. In my opinion we have these ashes here for you to use. Arise and make medicine. That's all.

Here the priest summons those who wish to be cured to come forward and stand near the fire to receive the administrations of the False Faces.

The masked waiters pass the medicine water. Every one drinks all he can. Two Husk Faces watch the doors to insure that no one leaves or enters during the imbibing. However, they can sometimes be bribed with a pinch of tobacco.

There are dances for each class of Faces. An appointed singer straddles a bench, and borrowing a rattle, sings for the Common Faces alone. They stand up and dance and apply hot ashes to any patients whose dreams have required that they be cured on this occasion. Frequently, little boys who are wearing masks have to be held up by their elders in order to blow ashes on the patients' heads. Sometimes, a clever little fellow will puff the ashes at the patient from his upturned hand. At Tonawanda, the masked dancers cure each other. A matron distributes tobacco and they depart with their kettle of mush.

Next the Husk Faces perform, receive popcorn and bound out of the room.

The second part of the ritual, named "They place one foot ahead of the other" for one of its component dances, includes the Dance of the Door-keepers. The song commences. Two men, who are appointed from opposite moieties, appear wearing the medicine masks representing the great world rim beings. They dance with the matrons, each facing the woman of the other moiety. A couple dances in unison, hopping on the left foot while bending the right knee and then kicking out the right foot. At the same time they spar at each other with the extended left hand, pointing the thumb upward. The turtle rattles dangle by the loop on the handle. Now the matrons pair the men and women in couples who dance imitating the False Faces. They spar at each other and a bold woman will somtimes back a bashful man from the floor. A door-keeper looks inside once during each song.

Then they return and compel every one inside to join a round dance, from which the ritual takes its name, since a dancer lifts his foot, bumps his heel and sets it down again ahead of the other. One door-keeper directs the dance, while his cousin watches the door to see that no one escapes the ritual.

The member who wears the mask to impersonate the door-keeper is supposed to know the members of the society. You can pick out the members. They look scared. They look at you hard, or they pretend to be busy about some other business of their own. You can discern them through the mask. If any are reluctant to join, you have the power to force them, a strength against which they dare not resist. Sometimes fights occur. If one is not able, his partner, the other door-keeper, will help him. Members *must* dance.[15] Those who resist become possessed.[16]

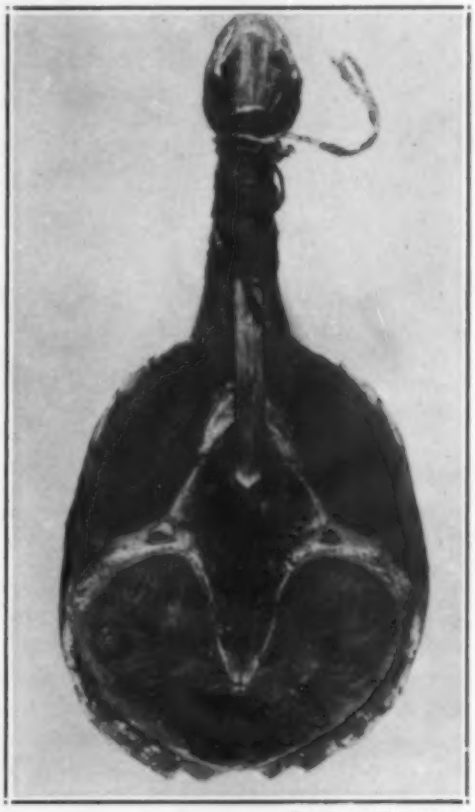
The round dance continues until certain songs request them to blow ashes. They repeat their square dance with the two matrons, blow ashes on their heads, receive tobacco and depart. The feast is hulled corn soup.

Although I have outlined the great public ritual, the same general pattern holds for private medicinal rites. The only difference is that the priest mentions the parson's name in the tobacco invocation. Then the complexity of the ritual depends on the number of orders to which the patient belong.

The simpler ceremony of the Common Faces alone has been vividly treated by Ernest Smith, a Seneca Indian artist of the Tonawanda reservation, in the accompanying painting.

The Blowing Ashes Rite

The setting is the interior of a bark house, common among the Iroquois a few generations ago, and the time is presumably an evening of the Mid-winter Festival. In response to a dream, the host has prepared a kettle of mush, or False Face pudding, and summoned the False Faces. The announcer, who is painted sitting on the bench, has returned thanks to all the Spirit-forces, explained the purpose of the feast, and invoked the Faces-of-the-forests with burning tobacco. They have entered. The singer straddles the bench to beat out the tempo for their dance, which they energetically commence, scattering ashes everywhere. They hasten to finish curing the patient, their host who stands before the fire, since they crave tobacco and hunger for the kettle of mush which he has set down for them. A tall, red-faced fellow vigorously rubs the patient's scalp before blowing the hot ashes into the seat of the pain. A dark one moans anxiously while rubbing hot ashes between his palms prior to pouncing on his victim's shoulder and pumping his arm. Across the fire, a red face stoops to scoop live coals, while another impatiently shakes a turtle rattle.



Fenton Collection.

A MUD-TURTLE RATTLE.

[15] Chief Henan Scrogg of the Snipe clan at Tonawanda.

[16] Jesse Cornplanter.

THE CURING RITES OF THE COMMON FALSE FACES.
PAINTING BY ERNIE SMITH, SENECA INDIAN ARTIST OF THE TONAWANDA RESERVATION.

They are naked above the waist, but wearing the masks is said to protect their bodies from cold and their hands from the burning embers.

Although the real Faces are seldom seen now, modern Iroquois, especially little children, fear them. A being which has the power to control disease, who can also cause the same ailment which he cures, is a subject for concern. The degree to which the False Faces dominate the lives of the Iroquois is well illustrated in the testimony of a sophisticated woman of Shawnee and Cayuga parentage whom Dr. Margaret Mead met among the Omaha. The informant had long since removed from her own tribesmen, but her childhood impression remained.

I remember how scared I was of the False Faces; I didn't know what they were. They are to scare away disease. They used to come into the house and up the stairs and I used to hide away under the covers. They even crawled under the bed and they made that awful sound. When I was bad my mother used to say the False Faces would get me. Once, I must have been only four or five, because I was very little when I left Canada, but I remember it so well that when I think of it I can hear that cry now, and I was going along a road from my grandfather's; it was a straight road and I couldn't lose my way, but it was almost dark, and I had to pass through some timber and I heard that cry and that rattle. I ran like a flash of lightning and I can hear it yet.

THE TARPON IN THE PANAMA CANAL[1]

By Dr. SAMUEL F. HILDEBRAND
ICHTHYOLOGIST, U. S. BUREAU OF FISHERIES

THE tarpon (*Tarpon atlanticus*) long has held a place of high esteem among anglers and is considered by many to be the world's gamest fish. Whether caught on a hook or surrounded by a net it wages a terrific fight for freedom. The sportsman, when properly equipped, generally delights in hooking the tarpon. The net fisherman, on the other hand, almost hates to find them in his net, for the large, powerful fish (the largest one reported to date being 8 feet, 2 inches long) too often "run" through the net, leaving large gaping holes. Furthermore, the fishermen sometimes are endangered by the large fish, for if they do not succeed in breaking through the net the fish generally leap high into the air, occasionally striking a fisherman in their efforts to free themselves. Commercially the tarpon has little or no value, as in most localities the fish is not marketable. In Panama the natives and particularly the West Indian immigrants, however, are very fond of tarpon, which is known to them as "sabilo real," *i.e.*, king shad. Some fishing is done on a commercial basis and tarpons frequently are seen in the Colon market.

Although the tarpon has been sought far and wide by anglers, and to some extent by naturalists, throughout its range, which extends from Cape Cod to Brazil and through the West Indies, much of its life history remains a mystery. It is not known to the present day where its spawning grounds are. Nor have the manner of spawning, the spawned eggs and the early larvae been discovered.[2]

It had long been supposed that the tarpon, like some of its near relatives, passed through a leptocephalus stage similar to the eel. In this larval stage the fish is very strongly compressed, ribbon-shaped and almost transparent; certainly bearing no resemblance to the parents. A full grown leptocephalus, of those species that have been studied, is considerably longer, though not greater in bulk than the newly transformed young. For example, the leptocephalus of *Elops saurus*, known as the bonyfish in Panama, a relative of the tarpon, reaches a length of fully 60 mm, but during transformation it is reduced in length to about 20 mm. That the tarpon does pass through a leptocephalus stage was proven a few years ago, when the author of the present article described in *Copeia* (April, 1934) a young tarpon 20 mm long, which was in the transition stage.

This postlarval tarpon was taken in an estuary at Beaufort, N. C. It does not necessarily follow, however, that tarpons spawn in that vicinity. We need only to remember that both the American and European fresh-water eels spawn in the ocean between Bermuda and the West Indies, and that the European eel travels across the Atlantic in the leptocephalus stage and then transforms and enters fresh water, and the American eel similarly migrates to our shores before it transforms. Therefore, the postlarval tarpon taken at Beaufort may have been hatched far from the place of capture.

Young tarpons, of about 2 inches and

[1] Published by permission of the U. S. Commissioner of Fisheries.

[2] For the most complete account of the tarpon published the reader is referred to a book entitled "The Tarpon," by Louis L. Babcock, 4th ed., 1936, privately published.

upward in length, have been found by investigators in shallow stagnant brackish water pools at various places, as on Sanibel Island (Fla.), Andros Island (Bahamas), Puerto Rico and Haiti. However, these young were all fully past the leptocephalus stage.

It has been known a long time that adult tarpons inhabit Lake Nicaragua, a body of fresh water a hundred feet above sea level. Recently I. W. Miller (*Field and Stream*, May, 1936) reported more or less regular fishing for tarpon in the Rio Frio, which empties into Lake Nicaragua. The Rio San Juan, which is the outlet of this lake, has falls, the height of which is unknown to the writer. The late Dr. Seth E. Meek (Publication Field Mus., Zool. Ser., VII, 1907), who investigated the fishes of the lake, stated "It is hardly probable that they (tarpon and some other marine forms) have come up over the falls at the head of the Rio San Juan in late years." Dr. Meek, therefore, assumed that the tarpons were landlocked. However, no young tarpons seem to have been found in the lake.

Concerning breeding it can be stated only that tarpons with large roe have been taken from time to time. Such fish have been captured by sportsmen and investigators in June at Boca Grande, Fla.; and in March, April and May at Sanibel Island, Fla. Though there has been some conjecture that these fish spawn in the general vicinity where taken, the fact is that no one knows definitely where the reproductive activities take place. Presumably in the latitude of southern Florida spawning takes place during the spring and possibly summer.

It is evident from the foregoing remarks that the life history of the tarpon was still largely unknown. Therefore, the writer was eager to add something to the known facts of its life history while making an investigation of the fishes of the Panama Canal during the early part of 1935. He was stimulated, further, in devoting special attention to the tarpon by the claim of local residents that both adult and young tarpons were common in Gatun Lake, a strictly fresh body of water. The study was expected to shed some light, also, on the moot question of the use of the locks as a passageway by the tarpons and possibly other fishes. The time for the last mentioned study was particularly auspicious, as the Gatun Locks were dewatered for overhauling during the writer's visit.

The Investigation

The investigation was conducted principally along the following lines: (a) Local anglers were interviewed concerning the occurrence of the tarpon in the waters of the Canal Zone, particularly in regard to their occurrence in Gatun and Miraflores Lakes. (b) A search, principally for larvae and small tarpons, was made in Gatun and Miraflores Lakes and their arms and inlets. (c) Specimens of tarpon were secured and examined for the state of development of the gonads while the Gatun Locks were being dewatered.

It was definitely asserted by several anglers that adult tarpons are year-round residents in the strictly fresh water of Gatun Lake. A few native fishermen, operating principally on the upper part of the lake, in the vicinity of the entrance of the Chagres River, where the fish appear to be most numerous, angle for the tarpon more or less on a commercial basis. Heavy tackle, like that employed for catching sharks, is used.

One fisherman who catches tarpons to sell has built a board walk to deep water at the upper end of Gatun Lake on one of the banks of what formerly was the Chagres River. At the end of the little pier he has rigged a large pole about 25 feet or so in length, which tapers from about 4 to 5 inches at the base to about 2 inches at the small end. The pole is set at an angle of about 40 degrees to the

Courtesy William Ackerman

THE TARPON, *TARPON ATLANTICUS*

water and is supported near midlength by a post. The line with the baited hook is attached to the pole. When a large fish (tarpon) takes the hook the movement of the pole can be seen from a distance. By the use of this device the fisherman may stay in a cool shady place, conversing with friends, or possibly engage in other work, until the pole begins to sway.

The description of the native's method of fishing given in the foregoing paragraph is offered, aside from the interest in its uniqueness, to show that the tarpon is sufficiently numerous in the upper part of Gatun Lake to induce a fisherman to go to some expense and trouble to equip himself for the fishery. Others presumably fish just as much as the man who has the boompole, but in a less pretentious way. Americans, of course, fish for sport only. So far as could be learned, tarpons are about equally numerous throughout the year and the sport or fishery is not limited to any particular season.

The writer did not angle for tarpons in Gatun Lake; nor did he see any taken

Courtesy Dr. Herbert C. Clark

BOOMPOLE USED BY NATIVE TARPON FISHERMAN

ON UPPER PART OF GATUN LAKE. A LINE WITH BAITED HOOK IS ATTACHED TO THE POLE.

by others during his visits. However, he did see several large fish "break water" and partly show themselves above the surface, which unmistakably were tarpons.

The more or less regular occurrence of the tarpon in Miraflores Lake (the small fresh to brackish body of water situated on the Pacific slope of the Canal Zone between the Pedro Miguel and Miraflores Locks) was reported by such reliable informants as Mr. R. A. Cauthers, chief of the maintenance office at Pedro Miguel, and by Dr. Herbert C. Clark, director of the Gorgas Memorial Laboratory, who maintains a veterinarian station on the lake. The writer did not see this fish caught in the lake, though he saw a very large fish break water which quite certainly was a tarpon.

It was stated earlier in this article that the writer was informed by several natives of the presence of young tarpons in Gatun Lake. On one of the collecting trips one of the men who claimed that many young tarpons were present in the lake was with the collecting party. We had not been working long when this man called excitedly that we had captured a young "sabilo real." However, this "sabilo real" proved to be an adult silverside, *Menidia chagresi*, about 3½ inches long. Later many more silversides were secured and preserved. These fish were shown to two other natives, who had stated that young tarpons were common in Gatun Lake, both immediately exclaimed "sabilo real." It was evident that the men had mistaken silversides for young tarpons. The search for young fish, however, was continued. Collections were made in many different sections of both Gatun and Miraflores Lakes and adjacent streams, but no young tarpons were found.

The investigator was present to examine the stranded fish during the dewatering of the east side of Gatun Locks, from February 20 to 24, 1935 (the other side having been drained in January, before his arrival in Panama). Several large tarpons (exact number un-

known) were stranded in the upper chamber, which of course was drained first. Only one specimen was secured for examination, the rest having been taken away by the Negro laborers before the writer could get to them. After this experience the superintendent of the locks forbade the men to remove a single fish until the investigator gave permission.

The middle chamber contained eight large tarpons, ranging in length from 3 feet, 3 inches, to 6 feet, 8 inches. The lowest chamber contained none.

It seems of interest to state here that the west side of the locks, dewatered in January, according to Mr. H. M. Thomas, assistant superintendent of the Gatun Locks, contained very few fish and no tarpons, in contrast with a comparatively large variety of species and great quantities of the "bonyfish" (*Elops saurus*) and the "jack" (*Caranx hippos*) found in the east side. Mr. Thomas stated that a similar ratio has existed each time the locks have been drained for overhauling, which is done at intervals of about three years. The writer knows no reason for the difference in the abundance of the fish in the opposite sides of the locks. The information is given here merely as a matter of interest.

Only the two smallest tarpons taken in the locks, respectively 3 feet 3 inches and 3 feet 7 inches long, were males, both being nearly ripe. Of the seven females one contained large roe, one small roe and the others were undeveloped.

Tarpons generally are numerous at the foot of the spillway, a high concrete structure built in the great Gatun dam. The dam itself is so large and broad that a golf course is maintained on it. The dam and spillway together hold the large body of water known as Gatun Lake, which forms a considerable portion of the canal. The water necessary for operating the locks is obtained from this lake. When there is a surplus it is used in generating electricity for operating the machinery connected with the locks, and when there is still a further surplus of water it spills over the spillway from the level of the full lake to the old bed of the Chagres River near sea level. The water from the turbines, too, enters the old bed of the Chagres River below the spillway. It is in this usually greatly disturbed water that tarpons collect. Here the water was fairly astir with tarpons and other brackish and marine fishes when the writer made observations in January and again in March, 1924. I did not find the opportunity to revisit this particular spot in 1935, but was informed that the situation remained unchanged. At the time of my visits the anglers present (Americans) stated they did not care to catch tarpons there, as the fish were so numerous and so easily caught it was not considered sport. The fish seen and taken were rather small, all under three feet. It is understood, however, that large ones do frequent this place.

The late Dr. Seth E. Meek and the writer, while collecting cold-blooded vertebrates in Panama in connection with the Smithsonian biological survey of the Canal Zone in 1911 and 1912, found small tarpons, ranging in length from 12 to about 24 inches, rather common in the brackish water in the vicinity of Mindi and New Gatun, that is, along the sea level end of the canal. Also, one large one, 5 feet or so in length, delivered itself into the collectors' skiff in that vicinity by leaping high in the air, "landing" first on Dr. Meek's back (hurting him somewhat and frightening him badly) and then falling into the boat. Its head slipped under a thwart, giving the writer a chance to administer a stunning blow with an oar. No tarpons were seen in strictly fresh water at that time, that is, before Gatun Lake had been formed. The area now included in the basin of the lake was thoroughly sampled in 1911 and 1912, and it is believed that if tar-

pons had been present they would have been found.

Discussions

It is very evident from the foregoing remarks that tarpons are fairly common in Gatun Lake and that they also occur in Miraflores Lake. It does not follow, however, that tarpons spend their entire lives in these fresh-water lakes, for if the complete life cycle were carried out there the larvae (*leptocephali*) and small tarpons should be present. It has been shown in the preceding pages that during a fairly thorough search no larvae and no small tarpons were seen in the lakes.

Tarpons could reach Miraflores Lake only by passing through Culebra Cut and Pedro Miguel Locks, for the Pacific Ocean is not the home of the tarpon, as already stated. Since tarpons have reached Miraflores Lake by passing through the Pedro Miguel Locks, the writer knows of no reason why they can not go on to Panama Bay and the Pacific Ocean through the Miraflores Locks. However, to date the tarpon has not been reported from the Pacific.

Since it is definitely known that tarpons have passed through the Pedro Miguel Locks, it may be assumed with certainty that they also pass through the Gatun Locks. If the fish did not reach Gatun Lake by that route it would have to be assumed that they were present when Gatun Dam was closed in 1913, and that the fish now in the lake either were there in 1913 or have reproduced in the lake.

There is no evidence that tarpons were present in the vicinity, which now is the lake basin, before the dam was closed, as already stated. Furthermore, fish present as early as 1913 would be very old now, much older than the age usually attained by fish. Then, too, the fish would be expected, unless there was reproduction, to become scarcer from year to year. According to information obtained the fish, however, are increasing rather than decreasing in abundance. It seems highly improbable that reproduction is taking place within the lake, since the evidence obtained during the recent investigation, as already shown, is entirely negative.

It has been stated in the preceding pages that several tarpons were present in the Gatun Locks when they were dewatered in February, 1935. According to Mr. H. M. Thomas, assistant superintendent of the Gatun Locks (who has supervised the periodical draining of the locks from the beginning) some tarpons were stranded each time the locks have been dewatered. It is the opinion of the writer that the tarpons that are stranded, when the locks are drained, are not necessarily actually in transit either to or from the lake. It is believed, rather, that the locks are used by the tarpons (and several other fishes) as feeding grounds, for small fish and crustaceans were quite numerous during the recent inspection, and it seems probable that a new supply of food is brought down from the lake or enters from the sea level end of the canal when the locks are operated. The locks apparently are used, therefore, as feeding grounds, somewhat like the base of the spillway where large numbers of tarpons (and other species) collect, as already stated. However, the fish appear to stray away from the feeding grounds within the locks from time to time, some no doubt returning to the sea, whereas others pass on into Gatun Lake, and a few of these eventually go on across that lake, through Culebra Cut, the Pedro Miguel Locks and on into Miraflores Lake.

If the fish can pass through the locks to Gatun Lake they surely can return by the same route. The fish, indeed, had to pass "down" and through the Pedro Miguel Locks in order to reach Miraflores Lake. Therefore, they certainly can, and no doubt do, go "down" the Gatun Locks

THE MOUTH OF THE RIO COCOLI, MIRAFLORES LAKE
WHERE TARPONS ARE OCCASIONALLY SEEN.

and out to sea at will, or as the necessities of life or reproduction require it.

The foregoing remarks seem to require an explanation, for the benefit of the reader who may not be familiar with the construction and operation of the locks of the Panama Canal, of how the fish manage to pass through the apparent obstruction.

A brief description of the passage of a vessel through Gatun Locks will illustrate also how a fish—a tarpon, for example—may find its way through the locks of the Panama Canal. In the first place Gatun Lake when full is about 85 feet above mean sea level. Therefore, a vessel passing from the Atlantic Ocean to Gatun Lake must be lifted from sea level to the level of the lake. This is done with a series of three equal lifts in close succession. The boat enters the lowest chamber of the locks at sea level. Heavy iron gates are closed behind it. Water is let in from Gatun Lake until the water level of this chamber reaches that of the second or middle one. Then the gates in advance of the vessel swing open and the boat enters the middle chamber. Now the seaward gates of this chamber are closed behind the vessel, and as before water is let in from Gatun Lake until the water level of the middle chamber equals that of the upper one. When that level is reached the gates at the bow of the vessel are opened and the boat passes on to the third or upper chamber of the locks. After the gates between the second and third chambers have been closed the water in the upper one is raised to the level of Gatun Lake. The vessel is now ready to sail out into Gatun Lake. To lower a vessel from Gatun Lake to the sea the process, of course, simply is reversed.

The locks on the Pacific side are operated in the same way. There is only the difference that the three flights are not all together. One flight is located at Pedro Miguel and two are at Miraflores on the other side of Miraflores Lake about four miles away.

A fish certainly could follow a vessel through the locks in either direction, providing of course that it could endure the rather sudden change from salt to fresh water or *vice versa*. However, the fish

does not have to pass through the entire series with any one vessel, as each chamber contains ample water at all times for the welfare of the fish. Therefore, it may stop in any one chamber for an indefinite period of time, providing sufficient food is present. Should food become scarce, or the *wanderlust* get strong, or the urge to spawn come, the fish may follow a vessel to a higher or lower level. Or it even may go from one chamber to the next (one at a time) in the direction opposite to the course of the vessel, as there is nothing to prevent it from swimming from one chamber into the next one while the gates are open.

It is evident from the foregoing discussion that the chief barrier to fish formed by the locks is the change from salt to fresh water and *vice versa*. A fish that can endure such changes in density should have no difficulty in passing through the locks. The tarpon evidently can accommodate itself to such differences in salinity, and the evidence at hand, as already indicated, shows quite conclusively that this fish does use the Gatun Locks (and the Miraflores Locks to some extent) as a passageway and probably as a feeding ground.[3]

It has been stated that three ripe or nearly ripe tarpons (two males and one

[3] Since this manuscript was prepared the writer has examined the air bladders of several tarpons and found that they contain a comparatively large amount of lung tissue showing that the fish are not entirely dependent upon their gills for oxygen, which may be the reason why they can change from salt to fresh water and *vice versa*. A full account, with a figure of the structure of the air bladder of the tarpon, is included in Mr. Louis Babcock's book "The Tarpon" (Fourth Edition), 1936, pages 48 to 50.

Courtesy Panama Canal

GATUN LOCKS, SHOWING SEA-LEVEL END OF CANAL

IN BACKGROUND. ONE SIDE OF LOCKS IS EMPTY; A SHIP IS IN TRANSIT "UP" THE LOCKS (MIDDLE CHAMBER) IN THE OTHER SIDE.

female) were present among nine specimens examined in the dewatered locks at Gatun. No evidence whatsoever indicating that the tarpon spawns in the fresh waters of the Panama Canal was secured. It seems probable, therefore, that the ripe fish seen in the locks were enroute to their spawning grounds somewhere in the sea.

It was stated in the introductory remarks to this paper that the spawning grounds of the tarpon have not been found. Neither has the recent investigation helped greatly to discover the secret. It can only be stated here, as already shown, that the results of the investigation indicate that the tarpon does not spawn in the fresh waters of the Panama Canal.

Several investigators have taken young tarpons, all past the larval stage, in shallow salt and brackish water lagoons, as pointed out in the introductory remarks. It does not follow, however, that such places are spawning grounds. In fact, it is highly improbable that large fish, like the tarpon, would go to such places to spawn. Furthermore, the leptocephali undoubtedly would have been taken before now if they occurred in such places or in inshore waters. The writer ventures the opinion that tarpons very probably spawn quite a distance off shore and in deep water.

The young, as already stated, pass through a leptocephalus stage like the eels. It seems entirely possible that tarpon larvae, like fresh-water eel larvae, travel long distances. The larvae of the European eel are known to cross the Atlantic Ocean from deep water, lying between Bermuda and the West Indies, and those of the American eel migrate from the same general vicinity to the American shores. The young eels do not attain the adult form until they reach the mouths of the rivers they ascend, at the age of about one year for the American and about three years for the European eel. It does not seem unlikely therefore that tarpons, too, spawn considerable distances off shore and that the young make long migrations. The single specimen in transition from the leptocephalus to the adult stage, described by the present writer (see reference in the introduction), taken in an estuary at Beaufort, N. C., may have been enroute to a quiet, shallow lagoon or swamp, for such places appear to be frequented by small tarpons. In the light of the evidence offered the writer would search for the leptocephali of the tarpon in offshore waters.

It has been stated on a preceding page that it has been supposed tarpons spawn in the spring and summer on the west coast of Florida. Investigators arrived at this conclusion because fish with large roe have been taken there during that time. By the same criterion, it may be deducted that spawning probably takes place off the coast of Panama during the winter and spring, the entire period during which fish with large roe occur there having not been determined.

Summary

Some important published information concerning the life history of the tarpon is reviewed. It is evident from this information that much of the life history of the tarpon remains unknown.

The occurrence of the tarpon in the waters of the Panama Canal is discussed, the discussion being based largely on investigations and observations made in 1911, 1912, 1924, and especially in 1935. It is shown that tarpons were present and apparently rather common, in the brackish to fresh water swamps and canals in the vicinity of Mindi and New Gatun in 1911 and 1912, before the canal was completed. It is stated, also, that no tarpons were found at that time in swamps and streams now included in the basin of Gatun Lake. In 1924 tarpons were numerous at the base of the spill-

way of Gatun Lake, a situation which apparently remained unchanged in 1935. Adult tarpons were common in some parts of Gatun Lake in 1935, and they also had reached Miraflores Lake, from whence they apparently may descend to Panama Bay, though no evidence has been secured that this has taken place. Young tarpons were mistakenly reported by native fishermen from Gatun Lake. No evidence was secured that they occur there.

Several large tarpons were stranded when the Gatun Locks were drained for overhauling in 1935. According to information offered by canal employes tarpons have been stranded there at each previous dewatering.

It seems probable that the Gatun Locks are used more or less regularly as a passageway, and probably to some extent as a feeding ground, by tarpons. Fish should not find it difficult to pass through the Panama Canal Locks in either direction, providing they can endure the change from salt to fresh water or *vice versa*. The tarpon evidently can endure the change. An explanation of how the fish may go through the locks is offered.

Three of the nine large tarpons examined when stranded during the drainage of Gatun Locks in February, 1935, contained large roe, indicating that at least some of the fish in the latitude of Panama spawn during that month.

The spawning grounds of the tarpon remain unknown. The author expresses the opinion, supported by some evidence, that they probably lie in deep water some distance off shore.

Tarpons pass through a leptocephalus stage, but the leptocephali have not been found. A specimen in transition from the leptocephalus to the adult stage, however, has been described.

Acknowledgments

The writer wishes to express his sincere gratitude to Dr. Herbert C. Clark, director of the Gorgas Memorial Laboratory; to Major W. E. R. Covell, in charge of maintenance of the Panama Canal; to Mr. H. M. Thomas, assistant superintendent of the Gatun Locks; to W. H. W. Komp, of the U. S. Public Health Service; and to Mr. R. A. Cauthers, in charge of maintenance at Pedro Miguel, for assistance given in various ways. Without the cooperation of these gentlemen the investigation could not have been made. Special thanks are due Dr. E. W. Gudger for reading the manuscript and making valuable suggestions.

THE MEDICINE OF HISTORY

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UNDERSTANDING of any subject requires its observation from the largest possible number of view-points. In these days, when the manufacture of history is speeded up so highly, there is need of every possible view-point on history in order to understand the present, to use the past and to plan for the future. It is probable that medicine, as a discipline and a method, may provide a view-point of history different from and complementary to other view-points. The medical study of history certainly is not the only, and perhaps even is not the most important aspect of history. But without its medical components, history is much more difficult to understand and to explain. International relations develop out of domestic conditions and in both the health of individuals, leaders as well as populace, has a modifying and sometimes a controlling effect on the production and course of events. Again, the health of social aggregations of people en masse frequently influences their domestic as well as their external conduct. Understanding of these individual and national or social health conditions often explains historical events. The great difficulty here is that man is not inclined to use and apply scientific knowledge in connection with social problems.

ECONOMICS

More than on anything else, international relations and national histories are dependent on economics. For schematic purposes, economics can be reduced to sources of production, utilization of products and that great connecting link, communications. Each of these three has definite medical features, but none of them has yet received adequate consideration from the medical point of view.

COMMUNICATIONS

Communications includes the transfer of persons, commodities and ideas. Its story is the story of human culture and advancement. Originally limited to his own foot power, man has harnessed animals, steam, electricity, oceans and winds, made internal combustion engines and utilized the principles of the inclined plane, the lever and gravity, all to facilitate his means of transport. As new methods have been discovered, old ones have not been abandoned but merely reoriented for use. Speech has been augmented by writing, printing, telephone, telegraph, radio and teletype. Locomotion has advanced from land to sea and then to air. Each advance in transport methods has invariably brought new and unique problems of control. Traffic management always has unsolved problems because improvements can not be foreseen and old solutions are inapplicable.

Disease control is complicated by all forms of air travel, which in turn have made necessary a completely new division of medicine dealing with the selection of pilots and the safety of air passengers. The hazards of air transport have an important medical aspect both in prevention and in treatment of abnormal states resulting. The opening of new automobile highways, as in the case of the new route to Mexico City from the Rio Grande, brings problems of disease transfer in each direction by man, insects and other animal carriers; the problem of adequate eating and drink-

ing facilities both for normal nutrition and for disease prevention; the problem of hospital, first-aid and other medical service in route; and the problem of adjustment to changed climatic factors.

The serious increase of traffic accidents and deaths in the United States carries medicine at a bound into the field of engineering, road construction, police control, public education and fitness of drivers. Improved communications developed the present world-wide system of collection of vital statistics and contagious disease incidence. Famine prevention, epidemic control, disaster relief and quarantine are other outgrowths. Quarantine was instituted by the Venetians and Lombardians in the fourteenth century to inhibit commerce for the sake of excluding epidemic disease (plague) coming in from the Levant. To-day quarantine facilitates commerce by scientific control of the causes of epidemic disease. Such an extension of medical service was not dreamed of a few years ago. It illustrates the intimate relation between medicine and communications.

Population Pressure

The basic principles of economics—production, utilization and communications—have had among others two practical developments which also have important medical phases. They have eventuated socially first in population pressure. This is a variable principle. It is qualitative and not quantitative. Some regions are over-populated with two persons per square mile. Population pressure depends on the ability of a geographic region to support its inhabitants in reasonable comfort and happiness. It is a direct result of economic relations and it is itself a medical problem because individual and collective health are so closely connected with population density. Health is affected by the economic standard of living, by the culture types modified or produced by quantity of population, by the degree of sanitary control and by facilities for prevention of disease transfer. Death and birth rates become of primary importance and assume an intricate reciprocal relationship with the other factors just noted. Infant survival and birth control are closely connected with religious, economic and cultural ideas, which tend to become compulsive. Population pressure tends to natural readjustment of equilibrium, and when this natural course affects nationalism or national economics, artificial controls tend to appear. These in turn lead to social unrest, disputes and wars.

Military Establishment

The second great development from basic economic principles is the growth of the police power and the entire military establishment. As man assumes social relations, social restraints become necessary, unless he is to live in that state of exalted individualism called anarchy. Social restraints lead to the institution of police power, which is as important from the health standpoint as with reference to crime prevention. National military establishments are part of the institution. Their effectiveness rests primarily on health considerations, just as their utilization is based on original economic causes. Domestic health of a nation is improved and maintained by various applications of police power. Wars and international economic competitions at once reflect health states in the countries concerned.

A verse by Ogden Nash expresses the mixed forces of social and economic restraints, militarism and population pressure.

> The turtle lives 'twixt plated decks,
> Which practically conceal its sex.
> I think it clever of the turtle,
> In such a fix to be so fertile.

Definitions

Before proceeding to illustrate our subject from the evidence of history itself,

it is well to establish a few definitions. These will make more definite what is meant by the influence of medicine on history, or what we call in brief the medicine of history.

In the first place, the term "nation" has often very inexact connotations. By it we mean here an aggregation of people having in common one or more of three things—a common origin, a common history or a common language.

In the second place, we define medicine, in the words of Webster, as the prevention, cure and alleviation of disease. Nothing is said as to systems or cults or sectarian ideas, all of which have no meaning for the real physician. The collection and utilization of all agents and methods from any and all sources, which may be of use in the specific case at issue, is the province and custom of medicine. Medicine therefore is concerned with study and improvement of the state of health of the individual and of social aggregates.

In the third place, we must define health, a most difficult thing to do because health may be good or bad or mixed, and because health is a composite of so many variable factors. Perhaps the best definition is to call health the average relationship between the individual and his environment. To study or evaluate health then requires exhaustive study of the total environment, a field properly called environmental medicine.[1] Reflection makes it plain that to draw a sharp line of demarcation between individual and environment is most difficult. To change or remove the individual at once radically changes the environment. To change the environment at once changes the individual. The two interpenetrate to a confusing degree. The philosopher would say that they are the same. The biologist would set up rather arbitrary and elastic boundaries as working hypotheses in his study. From the standpoint of history, attention must be given to the enormous influence on health of the environment of which the individual is a part. The interplay between the hereditary endowment (individual or racial) and the compelling force of environment must be understood in order to understand why individuals and nations act as they have acted.

[1] See A. C. Reed, *Science*, November 15, 1935. Also see J. W. Bewes, "Human Ecology," Oxford University Press, 1935.

Individual Illustrations

All historical characters lend themselves to illustration of the proposition that individual health has a bearing on public acts and policies. A few may be selected at random, from Julius Caesar, whose powerful sex urge was turned into channels of military organization and achievement, down to the leading dictators of our time. Napoleon showed the interesting combination of great egotism, vigor and driving energy in a man physically small. His compensations and adjustments furnish an illuminating commentary on his career and on the development of his great genius and world-embracing vision. It is to be noted that his post-mortem examination showed a complete atrophy of the testicles, and one can not help wondering as to the correlation between this progressive atrophy and the declension of his political and military genius. Failing physical vigor easily leads to a compensating program which may be grandiose and even fanciful in a person of driving imagination and egotism. We would like to know about the condition of Napoleon's cerebral arteries. His death from gastric cancer was a terminal accident which did not concern his earlier public life.

The sixteenth century saw the rise of England's great King Henry VIII, the man who rescued England from her insularity and made her a nation with world influence and destiny. He it was, the first sailor king, who laid the founda-

tions of British sea trade and the British navy. A man of aggressive strength, both physical and mental, he showed two outstanding medical peculiarities. He was unable to produce a male heir who could succeed him, and in his early middle life he began a progressive physical and mental degeneration which terminated in his death. Both of these things had serious and determining results on the English succession and on English history. Both were due to the spirochetes of syphilis. The spirochete which causes syphilis is no respecter of persons and is strangely as uninfluenced by ignorance of its presence as it is by disbelief in its potency. It did for Henry VIII very efficiently and conclusively. What he would have done and what England might have become, lacking the activities of the spirochetes in Henry's brain, is a matter for speculation only. Whether for worse or for better, in any case, both would have been considerably different. Even his matrimonial succession would have been greatly altered.

It is doubtful if history records an example of sheer cruelty, sadism and mass torture that exceeds the record of Ivan the Terrible. His wholesale murder of populations and his innumerable tortures and murders of individuals and groups flowed in a steady stream from another brain invaded by the spirochetes of syphilis. The result was a set-back to Russian social progress which even the great Catherine could not undo.

Queen Elizabeth may have owed her physical and psychologic make-up to the abnormalities of her father, Henry VIII. There is no doubt that her masculinity strongly influenced her public policies and also prevented her from ever marrying. Following the new policy of her father, she stimulated the formation of the British empire in India through the English East India Companies and at home consolidated the central power of England. While her unmarried state held a constant lure before the diplomats of Europe, it also settled the English succession. A normal femininity might not have led to better or worse results, but they certainly would have been different.

In 1412 there appeared a figure who changed the story of France and became one of the world's most tragic and romantic heroines, Joan of Arc, the illiterate peasant girl of Domremy, who died at the age of 19, without ever experiencing normal adolescence. In place of sexual maturity she heard voices and developed a mystical sense of mission and leadership which were abundant compensations and which fully explained the superstitious awe in which she was first held and the bitter animosity which she later aroused. Aberrations of physiology were associated with compensatory aberrations of psychology. Sex repression and infantilism pursued their characteristic course. And the result was an impact on history and legend, and the production of a half-mystical figure differing surprisingly in meaning, whether observed from the emotional or the rational point of view.

One other feminine figure of history must be mentioned, the Empress Theodora. In the sixth century, the austere and ascetic Justinian, emperor of the Eastern Roman Empire, at the age of 40 married the 20-year-old Theodora, courtesan and prostitute of Byzantium, whose reputation almost rivaled in extent that of the emperor himself. With her elevation, Theodora seems to have turned her charm of personality and great intellectual force into new channels. Her origin, background and earlier life combined with her mental vigor to make inevitable the remarkable influence she had on Justinian when he codified Roman law in his Institutes and Code. Here for the first time woman was accorded definite civic rights. Theodora was perhaps the first great feminist and

her influence has been multiplied down to the present. It is understandable only when her story is understood with its psychologic and physiologic foundations.

It is worthy of passing comment that Nietzsche and Lenin both suffered from syphilis of the brain, and general paresis is notorious for its tendency to grandiose delusions and unsettled judgment. Coming down to more recent times, we note the tragic pair of the great war, Kaiser Wilhelm II and Woodrow Wilson. The withered arm and efforts at compensation in the former accompanied mental brilliance, overweening ego, unbalanced judgment and eventually perhaps a paranoid status. The calming effect of asylum life, whether at Doorn or at some well-recognized institution in the United States, is well known. One can only speculate as to when Woodrow Wilson began to be influenced by the progressive degeneration of his cerebral arteries, which finally wrecked him. Certainly an effective cerebral circulation might have modified his courses and given him more vigor to carry them through.

We have then finally to consider the application of a medical summary to the two leading present-day dictators. The excellent studies of John Gunther on Hitler can be summarized in a few words. Gunther finds Hitler to be a man lacking in education and culture in any sense of the terms, a man who never reads, who is essentially weak and whose asceticism is born out of fear of temptation. He apparently is not a sex pervert, and on the contrary seems to have no sex interest, due to infantile fixations. Gunther characterizes him as a frustrated hysteric whose only release is in speaking. Such a summary surely lends understanding to a character otherwise most difficult of interpretation.

The other front-page dictator, Mussolini, is characterized by Gunther as a man highly educated and sophisticated, in robust health, whose hero is Julius Caesar, and who, being of the same height (5 feet 6 inches) as Napoleon, also likes to wear a corporal's uniform. He is very superstitious and violently in love with violent movement and speed. Out of his early and frequent prison experience, he has developed a claustrophobia, a fear of closed places. He is a man of tremendous egotism and megalomania, out of which, one might interpolate, are easily grown the seeds of paranoia.

Such illustrations, selected rather at random from an abundance of historical figures, show that the conduct of men in public as well as in private life can be influenced, modified and even controlled by purely medical factors of individual health. Hardened arteries, grandiose ideas, psychologic repressions and physical disease due to infections, reflect their results in events. History has a large medical component, which contributes in no small degree to understanding of history itself.

Mass Illustrations

We turn now to the effects of various states of health, that is, various medical factors, which are related to the history of man en masse, of social aggregates, nations and races. Once more we must start with the principles of human ecology and communications, which have been summarized above.

Human Geography

Human geography comprehends the bearing on human health and activity of geographic factors of the environment. Bowman, in his wonderfully stimulating book, "Geography and the Social Sciences" (1934), says:

> Earth facts do not determine the form and nature of human society in development. They condition it. . . . The relations are reciprocal. There is nothing in earth facts as such which inexorably dictates public policies, either national as in the case of the conservation of

limited resources, or international with reference to the distribution of such resources throughout political divisions and sub-divisions. Such facts, we repeat, condition policies but do not determine them. . . . Earth facts change in significance with man's changing activities, his useful or wasteful exploitation. . . . Thus while particular scholars may confine their attention almost entirely to so-called objective earth facts, those who *select* earth facts and organize them in relation to mankind are operating with respect to social knowledge and thought as well as with respect to earth facts.

The same idea is developed by J. W. Bewes in "Human Ecology" (1935). He says: "It must always be remembered that the functional relationship between environment and organism is a reciprocal one. The organism also continuously influences the environment." In his introduction to this volume, General J. C. Smuts, after epitomizing his own holistic doctrine, says: "The organism is not itself alone and in isolation. As a unit it is a mere static abstraction. The real dynamic unit is the organism functioning in its environment. . . . Life is living and living is an active reciprocal relation between organism and environment." Such is the essence of the thing called human geography. Because our means of observation are limited, it is much easier to trace the effects of environment on man en masse, in social aggregates, than on man as an individual. In the first place, then, our consideration extends to the broad subject of the relation of geographic environment to human history.

Illustrations of this topic are numerous and include most of the emigrations, racial and tribal transfers, that man has undertaken. Specifically a few examples may be noted.

In the twelfth century various environmental factors operated to stimulate a population outflow from the plateaux of central Asia. Population pressure became stronger as pasturage and water supply decreased. The Golden Horde poured out in three great waves. The first under Genghis Khan overflowed north China and for over two centuries fostered the Mongol-Chinese fusion which is still so much in evidence. The second wave flowed in successive inundations over the plains of north India, eventuating in the magnificence and high social organization of the Mogul (Mongol) dynasty whose imprint is imperishably fixed on Indian architecture, religion, politics and social structure. The third wave inundated Russia and for more than 200 years mongolized the government and people, leaving residues of Tartar blood which may help explain the history and the personality of Russia down to the present.

Again we see the story of the gradual drying up of Arabia and Mesopotamia. A land supporting probably nine million inhabitants was reduced to a capacity of about three millions. In the seventh century came the Prophet of Allah, with his invigorating and unifying evangelistic fervor. The Moslem started out westward. Egypt and all north Africa to the Atlantic fell before him. Then, strangely, this man of the desert, this horseman and nomad, this fanatical fighter, turned northward across the water into Spain, and never crossed the Sahara into the lush equatorial richness of Africa. The tsetse fly guarded the southern reaches of the Sahara and killed horses and live stock on which the Arab depended for life and transport. The resulting cultural increment in Spain was only interrupted when Ferdinand finally expelled the Moors in 1492. So much hinged on geography and geographic insects.

We find another illustration in Egypt, whose ancient glory fell before the onslaught of two lowly worms, Bilharzia and hookworm. The conquest of these two by scientific medicine in our own day may help materially in rebuilding the old foundations. So changing environment brought the anopheles mosquito to Greece

and to Rome, and the mosquito conquered great nations by the weapon of malaria. The story of the Conquistadores is shot through with medical hazards which changed, retarded and even stimulated the Spanish lust for gold and converts. The health of the world, through its communications, has been deeply influenced by man's controlled change of environment in building the great canals, Suez and Panama. These are a few demonstrations of human ecology, of the influence of environment on health condition en masse, of medical geography.

Epidemics

Social aggregates of mankind have been profoundly influenced since remotest times by epidemics. The record of plague is particularly interesting. Sweeping through Athens in the fifth century, B.C., it weakened the Attic manpower, paved the way for the Athenian defeat at Syracuse, probably struck down Pericles and was followed by the fall of the Golden Age of Hellas. In Justinian's time plague is said to have removed one third of the population of Byzantium. In the fourteenth century its fury was felt and the story was told for London by De Foe and Pepys. The epidemic of pneumonic plague in Manchuria in 1910, through the skilled leadership of Dr. Richard P. Strong and his American colleagues, led to practical methods of protection for the first time. To-day we see plague well established in the wild rodents over large sections of California and extending north and eastward to an unknown degree, with constant danger of human spread.

The story of typhus fever, as a war-attendant, as a scourge of populations and in its individual results has been well set out by Dr. Hans Zinsser. The records of cholera, yellow fever, smallpox and even measles are well known. Non-immune populations die like flies before these epidemics, as when measles depopulated many islands of the South Seas and in 1806 killed one third of the California Indians. Not fear, not an idea, not an immaterial emanation has done these things, but the unhuman and merciless virulence of germ and virus. Protection has never lain with magic, incense or refusal to recognize reality, but alone and always with scientific knowledge scientifically applied. The social scars of epidemics are not always lasting. In this they differ from endemic diseases. Influenza, in 1918–19, killed ruthlessly and then was gone. It did not drag out in chronic invalidism, social inefficiency and reduced physical and mental vigor. Nonetheless, epidemics have profoundly modified history and the course of events and have lost to mankind a huge amount of sadly needed intellectual, physical, moral and creative ability.

Endemics

Endemic diseases develop their natural history continuously in one place. Instead of periodic waves of pathologic activity and epidemic cycles, they operate steadily and, therefore, as has been indicated, are more prone to cause steady or even progressive social deterioration and ill health. Their morbidity rate is more important than their death rate. They weaken populations and individuals, reduce human initiative and predispose to other diseases. They depend on maintenance of natural balance between disease and host which, however, too easily operates to the disadvantage of the host. It is possible that the best biologic solution of the problem of epidemics would be to reduce them to a low rate of mild endemicity. Endemic disease in many instances has been a serious menace to human institutions and culture.

Such instances are seen in the world-problem of malaria. One chief reliance in treatment has become the effort to develop and utilize acquired immunity, but its attainment is attended too often by

uncontrolled and disastrous consequences. It is doubtful if the world-mass of malaria has yet been reduced, certainly not significantly, by the past 35 years of more exact knowledge of this disease. Malaria eradication is still too expensive in cost of personnel and engineering methods. And as soon as the flow of money is curtailed, malaria returns to its former preserves. We have no complete, cheap, safe and efficient method of cure or of prevention. Probably no disease to-day has a greater incidence the world around. Along with these considerations, the historian observes the racial weakening and backwardness, the social inefficiency and deterioration, which malaria produces. Its effects are evident in countless examples, from Greece and Rome, to southern Asia and the New World. Everywhere its ravages can be measured in social terms. Multiply this by the centuries of its parasitic existence and we have a problem worthy of the enormous expenditures of effort and money directed against it. We have, too, some appreciation of the effects of this disease on history, too often growing into a vicious circle where a weakened population sees its defences against malaria thereby further weakened. It is of course not a hopeless problem. For only a third of a century has the nature of malaria been understood. Human brains will triumph, and we can then forecast a renascence of peoples and regions now lying under its shadow.

Leprosy is another endemic disease with vast influence on the history of mankind. Here again natural and largely unknown causes, possibly aided by segregation, have considerably changed the habitat of the disease. There were doubtless good reasons why the discovery of America by Leif Ericson in the ninth century and the explorations of his successors never developed into a settled colonization. Among these reasons, probably, we can place the prevalence of leprosy in Scandinavia, which was a problem of sufficient weight to tax the public resources. Europe of the fourteenth century had some 22,000 leprosaria, over 2,000 in France alone. To-day this curious disease is dying out among the blacks of Brazil and increasing among the blacks of central Africa. The form of its infecting agent and the means of its spread are not definitely known. Yet as a public health problem the road to its solution seems open.

Hookworm disease has many parallels with malaria in its social significance. African sleeping sickness has kept the rich heart of a rich continent nearly barren of human culture. Syphilis takes its social toll and the slow process of racial immunity does not far outstrip effective methods of treatment and prevention. And so, through a long list, endemic disease makes its mark on history and all too often controls or modifies man's destiny.

Other Medical Factors

The influence of communications on the health state of nations has already been commented on. A corollary is the relationship of communications to famines and to relief after natural disaster, such as fire, flood and earthquake.

Health states are profoundly affected and not infrequently controlled by ideas of religion, sex and social organization. These are exemplified in every religion and in our own social order and can receive here mention rather than discussion.

Conclusion

The health of nations and of individuals exercises a potent influence on the manufacture of events and policies. The medicine of history may not always furnish historical causes, but it often and usually conditions human proceedings. For the fullest understanding of history the medical point of view has a clear contribution and can not be neglected.

RACIAL FOOD HABITS IN RELATION TO HEALTH

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IN the not very remote past man tried to appease the forces of his environment which were hostile to him by offering prayers and libations. The development of modern science has taught him that the environment may be controlled instead of appeased if he will learn the nature of the forces operating in it. The great mission of science is to put man en rapport with the forces of nature. The most modern science, nutrition, deals with the control of health in so far as it is affected by food—which is much farther than most people yet realize.

In the early pioneer days, when settlers were moving into the Middle West, a group of travelers came upon a lovely spot; water sparkling from a clear spring; all about was fresh verdure for their cattle. They encamped with joy, but this was soon turned to weeping, for the cattle sickened and the children who drank their milk died. From that region all fled in frantic fear as from a plague. What was the strange sickness which cursed so fair a spot? It took forty years to unravel the mystery of the so-called "milk sickness." Sometimes outbreaks swept away so many of the population that entire communities were abandoned. In 1927 it was discovered[1] that the disease was due to a plant which flourished throughout the eastern part of the United States and as far west as Nebraska and Oklahoma, called the richweed or the white snakeroot. With present-day knowledge, milk sickness is conquered by eradicating the obnoxious weed, not by running away from the spot where it grows.

Twenty years ago, when pellagra was a scourge in many a poor mill town of the South, the development of the disease in a family was a signal for the neighbors on either side to depart. They thought they were moving away from infection, but what really saved them was moving into a region of different food. It was many years after the first suspicion had dawned in the minds of scientists that pellagra might be associated with dietary deficiency before Goldberger and his associates in the U. S. Public Health Service were able to show that symptoms of the disease could be produced experimentally and cured again by dietary measures. Goldberger's experience taught him that "the suspicion of pellagra may with confidence be dismissed in one who is a habitual milk drinker and meat eater," and his successors, Wheeler and Sebrell, express the same idea thus: "In looking for cases of pellagra, the home surrounded by evidence of a good garden or a cow or two, a few pigs and some poultry, may as well be passed up (in the survey), for the chances are less than one in a thousand that pellagra will be found. On the other hand the home surrounded by last year's cotton patch will always bear watching."[2]

A field study recently made in South Carolina by Stiebeling and Munsell[3] affords further evidence that the distri-

[1] J. F. Couch, *Jour. Agric. Res.*, 35: 547–576, 1927.

[2] G. A. Wheeler and W. H. Sebrell, *Jour. Am. Med. Assoc.*, 99: 95–98, 1932.

[3] H. K. Stiebeling and H. E. Munsell, *U. S. Dept. Agric., Tech. Bull.*, No. 333, 1932.

bution of foods such as milk, wheat germ, yeast or canned tomatoes in suitable amounts to families in which pellagra is prevalent will greatly reduce the incidence and severity of the disease without any other change in the diet or the general living conditions. We have every reason to believe that before long researches in this field will give full control over this once mysterious scourge and explain why maize-eaters are peculiarly subject to it.

The effects of any considerable shortage of fuel for the human machine are so immediate—as evidenced by emaciation and unfitness for work—that there can be little misunderstanding concerning the need of an adequate energy supply. But partial shortages of a single essential chemical substance required in only minute daily amounts may only very, very slowly undermine health, and the connection between cause and effect is then more difficult to establish. In the famous "Wisconsin Experiment," in which all the dietary essentials known in 1906 were given to cattle in three different types of diet—(1) derived solely from the wheat plant; (2) derived solely from the oat plant, and (3) derived solely from the corn plant—it took three years to reveal that nutritional disaster would result from exclusive use of either the wheat or the oats ration, whereas good nutrition could be maintained into the second generation on the corn plant.[4] Research in many laboratories went on for about 17 years before we learned precisely what was required to make good the deficiencies of the wheat and oat plant rations. To-day we know that only three very simple and inexpensive things need be added—bone meal for calcium; common table salt for chlorine, and cod liver oil for vitamin A. These three can make all the difference between a miserable cow with a still-born calf and a fine vigorous cow with healthy offspring. No more beautiful demonstration of the triumph of the science of nutrition exists than in the contrast between the wheat-fed animals of 1907 and those on the suitably supplemented ration of 1924.

Now that we have eyes to see we find countless illustrations of the effects of inadequate diets. Many instances occur among animals living on the natural food resources of their habitat. A country gentleman in Alabama, residing in a rich alluvial belt adjacent to an area of sand dunes, was accustomed to hunt over these regions with his young son, and the son has told how his father often pointed out to him the greater size of the quail and other game in the alluvial territory as compared to those on the scrubby dunes. They had better food on the richer soil. Similarly, Larson, Duke of Mongolia,[5] has remarked that the wild horses brought in from the Gobi desert and properly fed would, even if six or seven years old, grow a couple of inches in height in a year or two and also show improvement in their teeth. McCollum has aptly said that the place to look for an old tiger is not in the wilderness but in the modern zoological garden, where he gets a scientific diet.

The controlled studies of white rats in nutrition laboratories have given a still clearer vision of the possibilities of improving health through diet. We may feed one pair of these animals a diet which will produce a fine litter of young through 30 generations, while a brother and sister pair, having the same heredity, and a diet differing only slightly from that of the other two, will grow to maturity; will be, so far as outward appearance goes, like the others but will lack the power of producing offspring. By simple changes in diet we can control the

[4] E. B. Hart, E. V. McCollum, H. Steenbock, and G. C. Humphrey, *Wis. Agric. Exp. Sta. Research Bull.* No. 17, 1911.

[5] F. A. Larson, "Larson, Duke of Mongolia." Little Brown and Company, 1930.

destiny of an animal very easily. We have it in our power to determine (1) whether it will grow or remain stationary in weight over long periods; (2) whether it will have a good appetite or so little that it dies of starvation with plenty of food in sight; (3) whether it will show the signs of old age early or maintain its vigor through a long active adult life. By means of this standard laboratory "tool," which grows 30 times as fast as a man and resembles him closely in nutritional needs, we may learn within a few years the cumulative effects of diet through many generations. Thus we have come to realize that we must not regard any race or nation's physical status as fixed, until we have found out whether better nutrition will alter it.

In case of human beings we also find in many regions very interesting examples of differences in physical vigor correlated with differences in dietary habits. One of the most striking of these has been furnished by the Rowatt Institute of Aberdeen, Scotland.[6] A study was conducted on two South African tribes, the Masai and the Kikuyu, with a view to possible improvement of the physical efficiency of the tribesmen as workers. Funds were provided under an agreement between the Colonial Office and the Government of Kenya, with the assistance of subsidies amounting to £6,000 from the Empire Marketing Board. These tribes live side by side in regions that do not differ as to climate and agricultural possibilities. The Masai are strikingly more vigorous than the Kikuyu. The fully grown Masai male is some 5 inches taller and 23 pounds heavier than the Kikuyu of corresponding age and sex. Also the muscular strength of the Masai, measured by dynamometer, is 50 per cent. greater. Similarly, the Masai women average 3 inches more in height and 27 pounds more in weight than the women of the other tribe. But the most striking differences occur among the children. Of the boys and girls up to 8 years of age, three fourths in the Masai tribe were graded as "good and very good" in physical development and none as "bad," while in the Kikuyu group, one half the boys and one third of the girls were graded as "poor to very bad" and less than one third "good to very good." The differences are more clearly indicated in the following table:

[6] J. B. Orr and J. L. Gilks, British Med. Res. Council, Special Report Series, No. 155, 1931.

PERCENTAGE INCIDENCE OF DIFFERENT DEFECTS IN KIKUYU AND MASAI CHILDREN

	Kikuyu		Masai	
	Male	Female	Male	Female
Bony deformities	62.6	43.7	11.7	14.6
Dental caries ..	13.7	13.1	1.6	3.6
Dental defects in general	40.0	28.8	8.3	7.3

What are the dietary conditions which make these differences? The Masai are a pastoral tribe and live mainly on milk, meat and freshly drawn blood. The Kikuyu raise large herds of goats but treasure them as a source of wealth and honor, *i.e.*, as money, not as food, subsisting mostly on cereals, roots and legumes. That the tribe does not die out is due to the fact that certain green leaves are definitely reserved for the women and that the children of both sexes up to 5 years of age as well as the women are given the ashes obtained by burning certain swamp plants and also edible earths from available salt licks.

All races of men have the same nutritional needs. They may be met in a great variety of ways, but all the essentials of an adequate diet must be furnished in suitable amounts or else there will ensue signs of nutritional insufficiency, as in the case of the Kikuyu, among whom such nutritional diseases as bony deformities, dental caries, spongy gums, anemia, tropical ulcer and tuberculosis are rampant.

What we have to do in order to understand such situations is to learn what kind of contributions different foods make toward these fundamental needs of the human body. In other words, we must learn to "take foods apart." The science of nutrition seems complicated because the actual nutrients can not be seen as such in natural foods and also because they are very irregularly distributed in foods. We can get a clearer understanding of the matter if we take a set of rods of equal length to

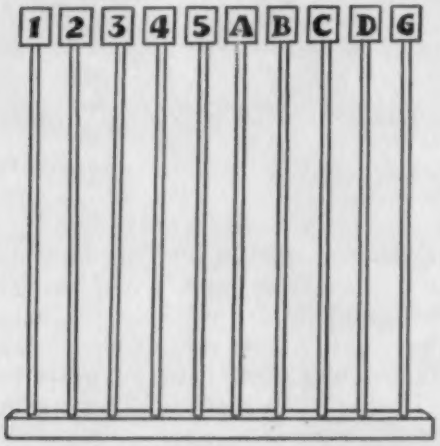

FIG. 1. THESE BARS, ALL THE SAME HEIGHT, REPRESENT 100 PER CENT. OF THE DAY'S REQUIREMENT FOR EACH OF TEN DIETARY ESSENTIALS. 1, CALORIES. 2, PROTEIN. 3, CALCIUM. 4, PHOSPHORUS. 5, IRON. VITAMINS A, B, C, D, G.

represent the day's requirement of each known dietary essential, and then use this set of "measuring rods" to tell us how far a given food will go toward meeting these requirements. By means of ten rods, each with a card bearing a letter or number, ten dietary essentials can be represented, the first five in this case indicating calories, protein, calcium, phosphorus and iron; the five with letters standing for five essential vitamins, A, B, C, D and G. All the rods are the same length, to indicate the total daily requirement as 100 per cent. of each essential. Not all the essentials of an adequate diet are represented here; but under most circumstances, by selecting natural foods known to furnish these, the others will be provided when the requirements for these ten are met. So this set of "measuring rods" will serve very well for practical purposes. Now if we wish to learn why advantages accrued to the Masai from high milk consumption we may observe what proportion of each of these required substances would be furnished by a quart of milk. Each card is moved down to a point on the rod which indicates the proportion of the total requirement furnished by the milk as shown in Fig. 2. Now it is quite easy to see why milk is recommended, wherever available, as the best foundation of any diet. It is interesting to inquire what could be obtained from an equal number of calories in the form of a cereal food such as whole wheat. The values for this food are shown in Fig. 3. The deficiencies of a cereal diet are now quite evident, even though the whole grain be consumed. When the bran and germ are removed, cereals contain very little of the so-called "protective" substances required, namely, minerals and vitamins.

By comparing Figs. 2 and 3 it is also easy to see that the cereals and milk can advantageously be combined. The bran and germ of grains are perhaps the greatest source of vitamin B in regions where grains are grown. Likewise, they furnish in readily available form iron and copper in which milk is low. The copper in the cereal aids in the utilization of the iron in the milk. All cereals are very deficient in calcium, hence in the milkless diet of the Kikuyu tribe, there is no good source of calcium except the salt licks and plant ashes, and as these are restricted to mothers and young children, the men and boys suffer most severely for lack of them.

The Kikuyu babies grow about as well

as the Masai babies, or even English and American babies, for the first three months. But their subsequent growth is progressively poorer. This is partly because of the inferiority of their mothers' milk, which reflects the poor quality of their diet, and partly because of the lack of any suitable supplements to mothers' milk available for infants. Nevertheless, it must be remembered that without their mothers' milk these babies would scarcely grow up at all. If there are no animals to convert grass and grain into milk, mothers must perform this task, and it is important that their diet be adequate for the purpose and that they continue to supply milk for several years after their children have begun to eat other foods. For it is now generally recognized that milk is indispensable during the whole period of growth if full development is to be attained. Baron Takaki (who is distinguished for the eradication of beriberi from the Japanese Navy), asked when past 80 years of age and still very vigorous how he accounted for his good health in his old age, replied that he was most fortunate in that, being the only child of his mother, he had the advantage of her milk for seven years. Certainly nothing could be more disastrous for children under five years of age than to deprive them of their mothers' milk without providing them a full equivalent in milk of some other species.

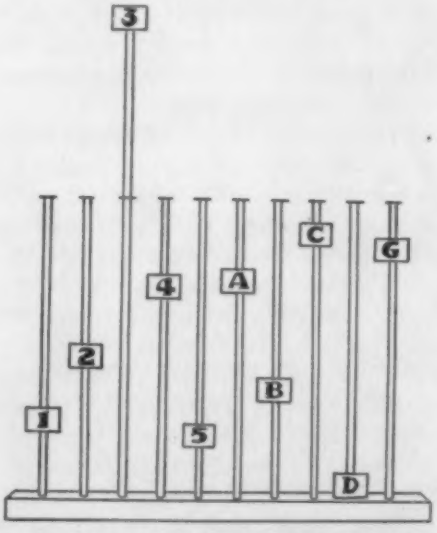

FIG. 2. CONTRIBUTIONS TO THE DIET MADE BY A QUART OF MILK. THE POSITION OF THE FIGURE OR LETTER ON THE BAR INDICATES WHAT PROPORTION OF THE DAY'S REQUIREMENT OF THE GIVEN ESSENTIAL IS FURNISHED BY THE MILK. THE VERY LARGE CONTRIBUTION OF CALCIUM No. 3 EXPLAINS THE UNIQUE PLACE OF MILK AS A SOURCE OF THIS ELEMENT.

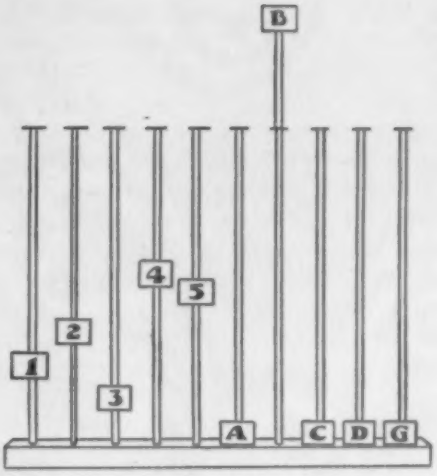

FIG. 3. CONTRIBUTIONS TO THE DIET MADE BY WHOLE WHEAT FURNISHING THE SAME NUMBER OF CALORIES AS 1 QUART OF MILK. THE RICH CONTRIBUTION OF VITAMIN B GIVES THIS FOOD A VALUE NOT ALWAYS APPRECIATED.

In sunny south Africa neither the Masai nor the Kikuyu lack vitamin D. For this reason, whatever calcium and phosphorus either tribe may obtain will be used to its full value for bone and tooth development. The bone diseases, dental caries and arrested growth among the Kikuyu are largely due to actual calcium and other shortages which no sunshine could remedy. They do not suffer from a disease which arises from lack of vitamin D, *e.g.*, rickets, as do children in regions of little sunshine. In the British Isles, rickets has been a scourge for centuries. E. Mellanby, now

secretary of the Medical Research Council of Great Britain, was the first investigator to show that rickets could be produced in puppies by a simple modification of the diet. He fed one set of puppies a ration in which the fat was butter or that in egg yolk and another the same ration, except that lard was the fat used. The development of rickets was prevented by the diet containing butter or egg yolk fat but not by that containing lard. This led to the discovery a little later by McCollum of vitamin D in these fats.

May Mellanby reported in 1931 a study of three institutions in the neighborhood of Birmingham, accommodating over 800 children, 5 to 14 years of age,[7] chosen because of similarity in their diets, "judged by all ordinary standards to be of a thoroughly satisfactory character." Every child cleaned his teeth once or twice daily and dental care was provided. In Institution No. I there was added daily to the regular diet according to age 1 to 1½ ounces treacle (golden syrup). In Institution No. II one group received from 1 to 1½ tablespoons of olive oil and a second group the same amount of olive oil in which a suitable amount of irradiated ergosterol (vitamin D) had been dissolved. In Institution No. III a group received a daily ration of cod liver oil. After two years it was found that while the number of carious teeth had approximately doubled at each of the control institutions, it had increased by only 50 per cent. at the third institution.

In many parts of the United States the regular inclusion of a small portion of cod liver oil or its equivalent for vitamin D is essential for the protection of every child, as the sunshine is not sufficiently abundant, but lack of this vitamin is not a problem of the sunny Southwest, or other regions where the days are radiant for long hours and life is mostly out of doors. In a land of sunshine, if diets consist largely of cereal food and meat, the problems of good bone and tooth development is rather one of securing sufficient calcium, phosphorus and vitamin A. In the museum of Indian relics in Mesa Verde, Colorado, one of the most interesting observations relating to the health of the ancient cliff dwellers is that pyorrhea was a common dental disease. This was probably due, at least in part, to deficiency in vitamin A, whose lack increases susceptibility to infections. Porto Rico is another country where, sunshine being abundant, rickets is almost unknown. Nevertheless, the people are suffering greatly from malnutrition. The children have not enough to eat even to meet their energy needs, and their diets are deficient in almost everything except vitamin D.[8]

In a large country like India, as in the United States of America, great contrasts are found between the diets of different sections. McCarrison, while British medical officer in charge of the Nutritional Research Laboratory at Coonoor, placed 1,000 rats on the characteristic diet of the Sikhs of Northern India, people whose physique is as fine as any in the world. Their diet is very simple, consisting of whole grains ground into flour, butter, legumes, raw carrots and cabbage, a little meat once a week; but they consume large amounts of milk. On this type of diet the rats throve, infant mortality was non-existent and no adults died except from old age. Old people are a problem to the natives, because they live so long.

McCarrison put another thousand rats on a diet characteristic of Central and Southern India. This consisted of cereals and vegetable fats, with scarcely any

[7] Interim Report of the Committee on Dental Disease of the Medical Research Council of Great Britain. Special Report Series No. 159, 1931.

[8] M. M. Eliot, U. S. Dept. of Labor, Children's Bureau Pub. No. 217, 1933.

fresh vegetables or milk. The infant mortality in this rat colony (as among the people in these regions) was very high and diseases of the respiratory, gastro-intestinal and urinary tracts, of the reproductive and nervous systems and of the skin were strikingly frequent. In this diet, there is an abundance of energy-yielding material and sufficient vitamin B to maintain a fair appetite, but there is a great deficiency of calcium, phosphorus, vitamin A and vitamin G, which would explain the prevalence of the types of diseases observed in the experimental animals, whose life had been led in a sanitary environment, so that the disturbances of health were due to diet and not to other factors. The findings are in harmony with what McCarrison says of the people who exist on these inadequate diets: "The general lassitude, lack of famines, plagues, wars, etc., originate as much in poor diet as in political or educational causes. Rice is a cereal of lower nutritive value than wheat in practically every respect except its energy value." McCay[9] states that even under favorable conditions a Bengali coal miner's output of work is little over one fourth of that of the European miner.

The nutritive differences in the diets of different districts in India are strikingly reflected in the growth of young rats reared upon them. On the "Sikh" type of diet their average weight at the age of 80 days was 285 grams, while on the Bengali type it was only 180 grams, and on the Madrassi type, with more rice replacing wheat, it was only 155 grams.

Yellow maize has the advantage of containing more vitamin A than other cereals, but it is deficient in the two or more pellagra-preventing factors which we now associate with the vitamin G complex. Meat-eating peoples get liberal amounts of these factors in the vitamin G complex, but muscle meat lacks vitamin A and is not rich in vitamin B. Pork muscle is an exception, being rich in vitamin B. This probably is the chief reason why poor people in the South, eating mostly corn, fat pork and molasses, do not get beriberi nor xerophthalmia, but do get pellagra. National diets as found in the past, and for the most part at the present time, are in each case an expression of the accumulated experience of the race inhabiting a given territory with regard to sustenance derived chiefly, if not wholly, from products available within the territory. As long as there was no scientific knowledge to guide dietary practices, the nutritional status of the people has been good or ill according to the extent to which the native resources could meet body needs, and provided that social customs and religious beliefs fostered their use instead of preventing it, as in the case of the African Kikuyu making no use of their goats for food. In the Philippine Islands, when they were taken over by the United States a quarter of a century ago, beriberi was rampant because of the widespread use of highly milled rice. It was practically wiped out of the army in three years by the substitution of 16 ounces of unpolished rice and 1.6 ounces of dried beans for 20 ounces of polished rice in the daily rations of the soldiers. But the natives could not be made to change their food habits by a military fiat. To-day, in the cities, child welfare stations save many children by teaching the mothers to give them tiki-tiki (rice polish extract rich in vitamin B), but in the rural districts the milling of rice has been perfected to produce the whitest possible rice and there beriberi is still wide-spread. This shows how little man's instinct guides him to an adequate diet!

In a diet where milk is freely used the deficiency of cereals in calcium and phosphorus has no special significance, milk being very rich in these elements, as

[9] Major D. McCay, "The Protein Element in Nutrition," p. 166, 1912.

shown in Fig. 2. Carnivorous animals get their calcium and phosphorus from bones, and herbivora from the large quantities of grasses and other greens consumed. Human children get it from their mother's milk during the period of most rapid growth, and whether they continue to develop well after the period of lactation is over depends in considerable measure on the amount of calcium which their subsequent diet contains. Southern China shows an interesting adaptation in a country where density of population makes milk-production extremely difficult. Hoh, Williams and Pease[10] have shown how the Chinese custom of cooking bones in the presence of an acid extracts appreciable amounts of calcium. A suitable gift for a prospective mother is a pair of pig's feet. She will hope by the time the baby is born to have accumulated perhaps two dozen pairs. These will help to support her body's demand for calcium during lactation. Older children and adults derive their calcium very largely from green vegetables, of which enormous quantities are consumed. Adolph and Wu, in making a diet to correspond to that used in Shantung province,[11] estimated 30 grams of cellulose as representing a man's daily consumption, an amount which Americans would find almost impossible to consume. This cereal-green vegetable diet is able to induce good bone and tooth development only when the body has an abundance of vitamin D made by the play upon the skin of brilliant and constant sunshine. In Northern China, osteomalacia, the disease of adults of origin similar to rickets, is endemic, owing to the combination of a diet consisting chiefly of cereals with an indoor habit of life. The women are most disastrously affected, as they are housed most closely, but opium smoking frequently keeps the men indoors too.

Nutritional handicaps are often accepted as a part of the race tradition. Classical European paintings show goiter in the most beautiful madonnas. In the past, in Switzerland and in France, cretins numbered hundreds of thousands. Now, thanks to the demonstration in 1917 by Marine and Kimball in Akron, Ohio, of the effective prevention of goiter by the administration of iodine to school children, there will never be such a development of the disease in our goiter belts. As a result of this study its incidence in Switzerland was altered from about 87 per cent. in 1918 to 13 per cent. in 1922. The best protection, in regions where plants and water do not furnish enough iodine, is usually the household use of iodized salt.

Diets not strictly lacking in any one essential may still be far from optimal for pregnancy, lactation and the growth of the young to full maturity. It is the common experience of nutrition laboratories that earlier maturity, greater size and vigor and deferred old age result from diets liberally enriched with minerals and vitamins. Such enrichment is more easily accomplished by the addition of milk than in any other way. A striking illustration of this is furnished by a study of four years' duration, made on English school boys by Mann.[12] The boys, 6 to 11 years old, were receiving a diet supposed to be adequate, but as they were under average weight and height for their age, various additions were made to their diet. The supplements were extra sugar (3 oz.), butter (1¾ oz.), water cress (¾ oz.) or milk (1 pint). With the exception of water cress, these additions were equivalent in calorie value. Mann says of the out-

[10] P. W. Hoh, J. C. Williams and C. S. Pease, *Jour. Nutrition*, 7: 535, 1934.

[11] W. H. Adolph and Mao-Yi Wu, *Jour. Nutrition*, 7: 381–394, 1934.

[12] H. Corry Mann, Med. Research Council of Great Britain, Special Report Series, No. 105, 1926.

come of this study: "The nutritive value of a diet which was originally chosen with every regard for the welfare of the children to be reared upon it could be strikingly improved by additions which in a quantitative sense were small. It is startling to learn, as we do now, that the addition of one pint of milk a day to a diet which by itself satisfied the appetite of growing boys, could convert an average animal gain of weight of 3.85 pounds to 6.98 and an average rise in height from 1.85 inches to 2.63."

Another striking demonstration of the value of a better diet for children was made in six industrial centers in Scotland and Belfast, Ireland. A daily portion of milk, varying from ¾ to 1¼ pints, was served to 1,400 children attending the elementary schools. Similar groups of children serving as controls received a corresponding number of calories in the form of sweet biscuits. In 7 months the increase in height and weight was 20 per cent. greater in the milk-fed groups[13] than those not receiving the extra milk. "In practically every case it was noted that the children receiving milk showed even where there was obviously poor maternal care, the sleekness peculiar to the well-nourished animal. Their hair had a glossy and bright appearance, their nails were smooth, resilient and looked as if polished, general alertness was common to all the children fed on milk. It was gathered from teachers and janitors that the children were much more boisterous and difficult to control." It is worth while to make every effort to get a milk supply, not only for children but also for adults. No other food enhances the nutritive value of the diet in so many ways at once.

Changes in racial habits may be disastrous if the people are living in nutritional equilibrium but close to the margin of safety. Native diets of the Eskimo, consisting largely of the whole animal, whether seal or fish or wild game, eaten mostly raw, and supplemented with eggs, when available, sufficed to maintain them in health. But the introduction of cereal foods (especially white flour) and sugar, diluted the diet, so to speak, as regards minerals and vitamins, with the result that nutritional diseases, beriberi, scurvy, rickets, night blindness, dental diseases and other less specific signs of malnutrition, have become widely prevalent, and it is now necessary to reeducate the Eskimo in order to cure the ills which have come as a result of the inclusion in the diet of foods lacking the nutritive properties of those formerly consumed.

Whole animals, eaten raw, will furnish all man's dietary requirements except vitamin D, which is richly supplied only by fish liver oils. A study of children in Norway belonging to three races, Lapps, Norwegians and Finns,[14] showed that the Lapps, although the poorest, with the lowest standards of housing and sanitation, had by far the least rickets, owing undoubtedly to the large amount (2 to 3 ounces daily) of fish oil which they consumed.

Even in a sunny climate where rickets is a disease seldom seen, a child should not grow up calcium-poor. If there are grazing sheep, there could be grazing goats, and if every child had even one cup of milk daily, this would not only help to guarantee calcium, but also excellent supplies of phosphorus, vitamin A and vitamin C.

The liver of the animal is especially important as a source of iron and vitamins A, B and G, as is shown in Fig. 4.

Mori, a Japanese physician, studying the eye disease prevalent among Japanese children, found it could be cured with chicken livers. This was one link

[13] G. Leighton and M. L. Clark, *Lancet*, I: 40–43, 1929.

[14] J. Kloster, *Acta Paediat.*, 12, Suppl. III, 1931.

in the chain leading to the discovery of vitamin A which not only cures this eye disease, called xerophthalmia, but is most important for the maintenance of a high degree of vigor in all parts of the body. Among the Indian tribes in the southwestern part of the United States, the liver of the sheep is highly prized as a food delicacy, and it is regrettable that sheep livers are not more abundant, for where the country is arid and green vegetables always difficult to obtain, there is danger of a scarcity of this vitamin. The grazing animal stores richly in the liver this important dietary essential. The milk-giving animal also conserves it in the milk fat. The goat, put into the herd of sheep to guide these less intelligent animals, is a splendid milk producer, and should be so treated as to insure maximum yield. Although corn is richer in vitamin A than other cereals, it would require from 1½ to 2 pounds of corn to yield as much as one ounce of liver. A child fed for a number of years his mother's milk will get a good start, and a deficiency of vitamin A will not show externally for so long a time that when disaster comes there is no thought of its connection with the diet. The tendency of the Indians of the southwest to substitute white flour, which furnishes no vitamin A, for corn and to dilute the meager supplies of this vitamin by lard, which also lacks it, will tend to nutritional disaster, just as the Eskimos' substitution of white flour and sugar for whole seals and whole birds, supplemented by many eggs, has resulted in wide-spread malnutrition. White flour can not safely be made a staple in a diet unless butter, milk, eggs, or green vegetables or fish liver oils are taken in sufficient quantities to insure rich supplies of vitamin A, and unless other foods are similarly chosen to guarantee a sufficiency of other vitamins and minerals.

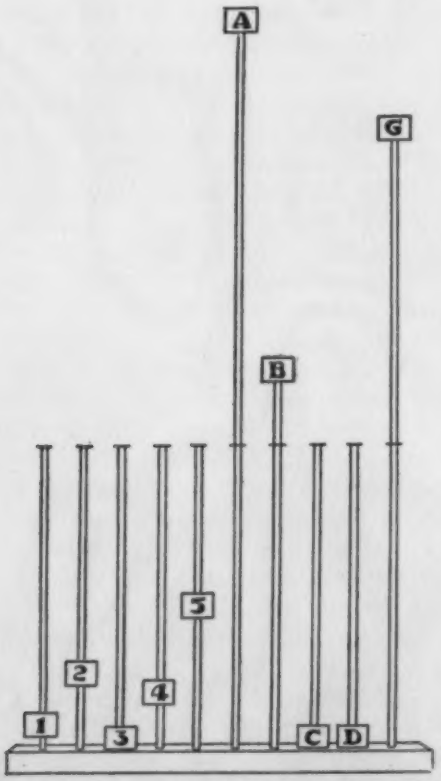

FIG. 4. CONTRIBUTIONS TO THE DIET MADE BY 100 CALORIES (2.7 OZ.) OF LIVER. THE OUTSTANDING CONTRIBUTIONS OF VITAMINS A, B AND G GIVE THIS FOOD A HIGH "PROTECTIVE" VALUE.

Where fresh fruits and vegetables are not obtainable, very large quantities of meat, if eaten raw, will furnish enough vitamin C to protect from scurvy. The meat of the narwhal (the fabled unicorn) is said to be delicious raw, when frozen hard and consequently very tender. The smooth mottled skin is considered a great delicacy, and a frozen square foot is a modest portion. Raw frozen walrus liver served with bits of fat is considered a delectable Eskimo entreé. According to Donald Macmillan,[15] an Eskimo family of four easily consumes four thousand pounds of meat a year, about half of which is eaten raw or frozen. On this diet, the Eskimo is supplied with sufficient vitamin C to escape scurvy.

[15] Donald B. Macmillan, *Am. Museum Jour.* 18: 161–176, 1918.

Stefansson in his Arctic expeditions has given evidence that full-grown men can subsist for long periods on a meat diet without scurvy. But in warmer climates, as raw meat may not be safe from infection or parasites, it is better not to depend upon it for vitamin C, because it is easy to get this vitamin from plant sources. Canned tomatoes are almost universally available and popular, and 1 to 2 ounces daily will protect any normal person, child or adult.

The science of nutrition has not only revealed dietary factors of unsuspected value for health but has given a new concept of the connection between diet and health. Understanding better the contributions which different kinds of food make to the diet as a whole we are able to choose more intelligently and thus to avoid the evils which so often result from the blind following of inclination. Moreover, we now have the power of ameliorating the evils of poverty by such simple protective measures as the liberal use of milk, tomatoes, cod liver oil, green vegetables and whole grain cereals. As Sherman[16] has so aptly said, "The longer lease of healthier and more efficient life which the newer knowledge of nutrition offers may be of very far-reaching significance to human progress, in affording fuller opportunity for the use and enjoyment of the accumulated and ever-growing body of knowledge, through education, association, and social inheritance."

Interest in the dietary customs of different nations and their influence upon health has been greatly stimulated of late by the Health Organization of the League of Nations. For the past 10 years the league has been engaged in such a study, but within the last few years fresh impetus has come from the economic crisis. An extensive report by Burnet and Aykroyd,[17] after visits to different countries to study their nutritional problems and the measures being taken to improve their health through better feeding, has just been published. Special conferences of experts have been called and others are planned to help bring about "marriage of agriculture and public health" through a better understanding of the nutritional needs and how to meet them. A special committee, including agriculture, economic and health experts, met in Geneva in February, 1936, and is preparing an extensive report for the next assembly.

[16] H. C. Sherman, "Food and Health," p. 205, Macmillan, 1934.

[17] Et. Burnet and W. R. Aykroyd, *Quart. Bull. of H. O. League of Nations.* IV: 2, June, 1935.

FATHER NILE AND EGYPTIAN AGRICULTURE

By Dr. W. O. BLANCHARD
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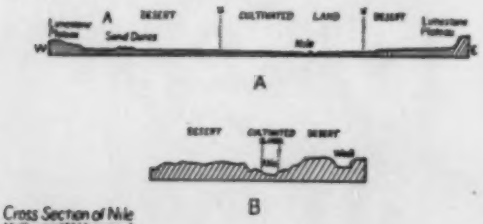
A Desert Oasis

Superficially, Egypt covers a vast territory, almost as large as France and Germany combined, but the real Egypt, the land upon which the Egyptians actually live and work, is but a tiny part, less than one twenty-fifth of the whole. A vast desert of sand and gravel, unproductive and uninhabited, but stretching across it, a long, thin thread of green, a garden, intensively cultivated and densely populated—this latter is the true Egypt. It is the world's largest oasis in the world's largest desert.

Here, on this wonderfully fertile flood plain, life was protected on all sides by great deserts, fertilized and watered by the never-failing Nile, and stimulated by the alternate productive and unproductive seasons, as determined by the rise and fall of that river's waters. Here in this favored spot grew up a great empire with an advanced civilization at a time when Europe was a wilderness. To-day it is the home of some 14,000,000 people, practically all of whom live within sight of the river; all are directly or indirectly dependent upon agriculture; and for all, the waters of that life-giving stream are absolutely indispensable.



Cross Section of Nile Valley in (A) Upper and (B) Lower Egypt

Fig. 1[1]

[1] Data for Figs. 1 and 4 were obtained from H. G. Lyons: The Cadastral Survey of Egypt, 1907. Cairo, 1908, and from H. S. Bey, Undersecretary of State, Ministry of Public Works, Cairo, Egypt, January 11, 1935.

A Land of a Single Resource

Egypt is a land of a single resource—a soil made fertile by Nile silt, but rigidly limited in extent. Minerals, water power, forests, fisheries—these are negligible. But the best soil in the world is useless without water, and Egypt is practically rainless. Alexandria, on the coast, has an annual precipitation of 8 inches, Cairo, 1.3 inches, and south of that city a shower is rare. Under the high temperature and porous soil conditions prevailing throughout Egypt, this rainfall is of negligible importance. The dependence upon artificial watering for the existence of every plant, every animal and every person in the country is both necessary and absolute. Water is the great limiting factor for life in the oasis, and Egypt is "the gift of the Nile" as truly to-day as it was in the time of Herodotus. No other country and no other groups of people of comparable magnitude are so dependent upon a single stream.

The Nile—A Remarkable Stream

The Nile is one of the world's greatest rivers and is in many respects a most remarkable stream.

(1) It is, with the single exception of the combined Missouri-Mississippi, the longest river on earth. From source to mouth it is some four thousand miles, and properly placed it would reach from Chicago to Western Europe. So long is it that it requires some three months for the flood waters to travel from Khartoum to Cairo.

(2) Its source is in Lake Victoria, the

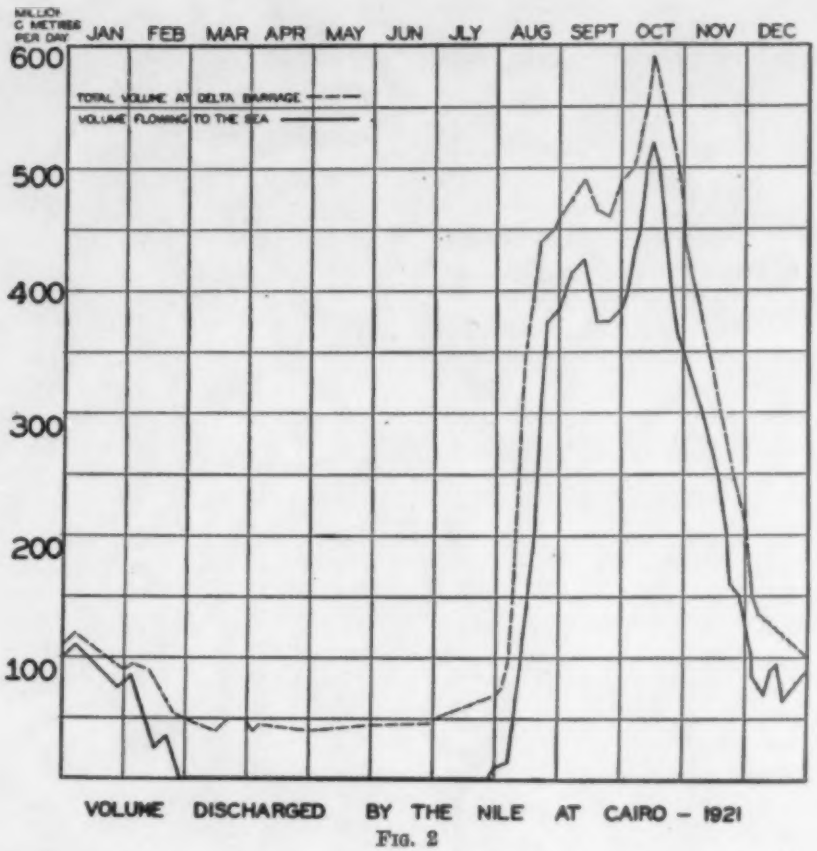


FIG. 2

second largest fresh-water lake in the world, lying at an elevation of three fourths of a mile above sea level in equatorial Africa.

(3) For the last 1,600 miles of its course, it does not possess a single tributary. Indeed so much of its water is evaporated or absorbed in crossing the thirsty desert that only about 3 per cent. of the precipitation over its basin is actually delivered at its mouth. The Mississippi and Amazon discharge about six times that proportion.

(4) It is most remarkable for the height and regularity of its annual floods and for the deposit of rich alluvium which its waters spread over the flood plain.

(5) Its long valley flood plain is mostly under ten miles in width, a narrow cleft in a low plateau of sandstone and limestone. It discharges through a large delta, about 150 miles in width and containing about three fifths of all the cultivated land of Egypt (see Fig. 1).

MAKING THE NILE WATER THE CROPS

Irrigation methods, according to the earliest known records, have changed but little down to the twentieth century. This system, commonly called "basin irrigation," operated somewhat as follows:

(1) The flood plain was divided into great shallow basins by low dikes. Seen from above in flood, the landscape suggested a huge checkerboard, some of the diked enclosures containing as much as 50,000 acres.

(2) By autumn, the flood waters, con-

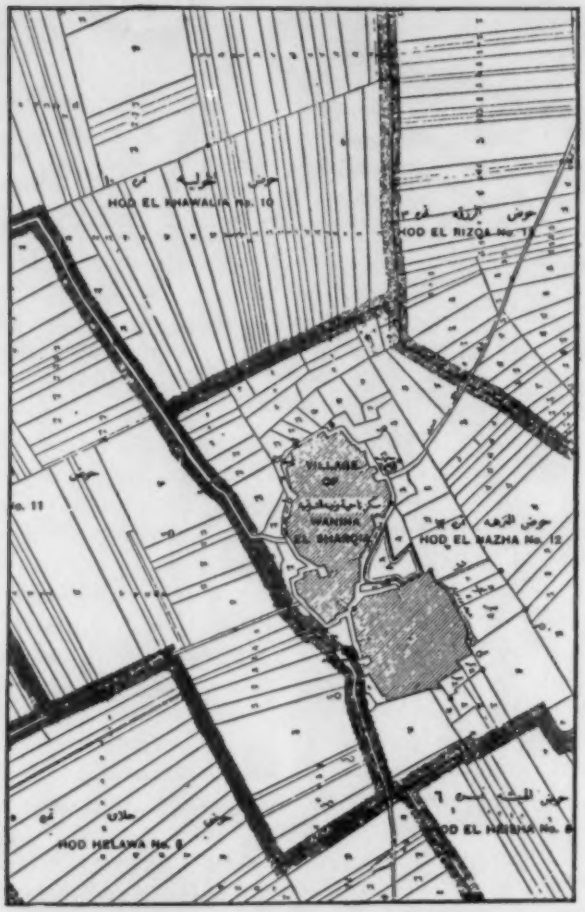


FIG. 3

tributed by the Abyssinian summer monsoon via the Blue Nile, had reached the lower Nile. A rise of thirty to fifty feet had transformed the river in August and September into a lake. The dikes held the water on the land even after the flood stage had passed. After standing for six to ten weeks, the little water remaining in the enclosures was then allowed to drain off into the low water Nile (see Fig. 2). It is estimated that during this period the average acre absorbed some 4,000 cubic meters of water and had had deposited upon its surface some six tons of sediment. This thorough soaking had to suffice for the moisture requirement of the whole season.

(3) Seeds of quick-growing winter crops, such as grain, clover, beans or peas, were planted in the mud. These grew, matured and were harvested in the spring with practically no rainfall.

(4) After the springtime harvest, the land lay fallow all summer—fields of mud, sun-baked and cracked—until the autumn floods came again and the cycle was repeated.

(5) Certain limited areas too high to

be reached by the normal flood waters or where it was possible to provide summer watering, were irrigated by various primitive devices. Shadufs, Persian water wheels and pumps were worked, often by hand, though sometimes by oxen. A shaduf worked continuously by two men could water about two acres; a water wheel operated by buffalo could take care of eight acres. Some of these are still in use.

This basin system, then, obviously had serious limitations. The amount of land capable of being watered was small, and a failure of the river to rise to normal flood level carried tragic consequences to the high level farms. In 1877, for example, almost a million acres of the higher fields were left dry, carrying starvation and death in its wake. It also meant that as a rule only one crop, a winter crop—a quick-growing crop—could be raised. On the other hand, the limited drain upon the fertility of the land and the film of mud left by the flood waters were sufficient to keep the soil at a high level of productivity for thousands of years.

The new system, called "perennial irrigation," depends upon the great dams and barrages, constructed after the English took charge, especially the Assuan dam. These are opened from July to November, during the normal flood movement, and the land is watered and the crops are planted as under the old basin system. But during the growing of these winter crops the dam gates are closed and the low winter flow, formerly wasted, is gradually stored behind the dams. Then, after the harvest, the stored waters, now at a high level, are fed into a system of canals which irrigate during the summer months. Thus, instead of one winter crop we now have two or more crops grown, and long season crops grown, such as cotton. This arrangement has the advantage of furnishing water during the hot season when maximum growth is possible. Incidentally, it increases the insect menace by providing food for them all the year through.

Problems

In general, the problems to-day, as in the past, center about the balance of *land* and *water*, on the one hand, and of *population*, on the other. Both these factors are susceptible of a considerable degree of control. However, thus far attention has been centered only upon increasing the food supply; little or no effort has been made to restrict the birth rate. The latter has, in fact, far outrun the means of subsistence. In the past 50 years it is estimated that the cultivable soil has been doubled, but the population has been multiplied fourfold. As a result there are now crowded onto that narrow flood plain some 14,000,000 people, the vast majority of whom are illiterate, miserably poor, hopelessly in debt, almost naked and half starved. A cotton rag, a bowl of corn mush and a few dung cakes (for fuel) constitute the sole reward for the daily toil of millions. One hesitates to say they are "making a living"; rather, they are "eking out a bare existence."

How closely the population presses upon the food supply may be appreciated by computing the size of the individual holdings. For many years, the average number of acres per land-owner has decreased until it is now less than two and a half. But this average does not reveal the real situation. That is still worse.

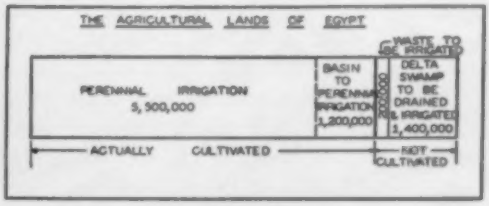


Fig. 4

Forty per cent. of all the cultivated land is in the hands of only *one* per cent. of the proprietors. As a consequence over two thirds of all the land-owners average less than one acre each! Some of the holdings are unbelievably small—less than one foot in width (see Fig. 3). These farmers must supplement their income by hiring out to larger landowners. In 1932 on several large farms on the delta the writer was told the average wage for farm hands was about $5.00 per month!

It is obvious, then, that of the various problems confronting Egyptian agriculture, none is more serious, none more pressing, than that of the education of the masses. While Egypt is the seat of one of the oldest civilizations, to-day, over 90 per cent. of the peasants are illiterate. Their farming methods are essentially the same as in the days of the Pharaohs. Above all, this education should include an understanding of the necessity of birth control, of sanitation and of hygiene. Egypt has the highest death rate of any country for which we have statistics, but its birth rate is likewise one of the highest—a terrible waste of human energy.

The second problem, or group of problems, has to do with increasing the quantity and the variety of agricultural crops. What may reasonably be expected in this direction?

It will be seen from Fig. 4 that of the potentially productive area in 1935—some 7,100,000 acres—only 5,500,000 acres were actually cultivated. The difference includes: (1) 200,000 acres of waste in Upper Egypt now not used but to be irrigated; (2) 1,400,000 acres of brackish swamp land on the Mediterranean border of the Delta, requiring both drainage (by pumping) and irrigation.

In addition, of the land already cultivated, some 1,200,000 acres produce but a single crop annually, because of a lack of water during the summer. This is to receive perennial, or year-round irrigation.

All the above proposals presuppose *more* water and in addition a *better regulation* of the supply. More dams and barrages, pumps for delta drainage, a second heightening of the Assuan Dam, together with added canals, are part of the program. Some of these projects will be in the Sudan (English) and others within the border of Ethiopia (Italian) and will involve cooperative agreements with those governments.

One further difficulty of Egyptian agriculture must needs be mentioned here—the need for crop *diversification*. Few countries are so economically dependent upon the production and export of a single commodity as is Egypt upon cotton. It is the all important—almost the only—money crop. Four fifths of the country's export by value is represented by this staple. Thus, with all their "eggs in one basket," price fluctuations of cotton bring prosperity or ruin to millions. Legal restriction of the maximum area which may be devoted to cotton has been the corrective used thus far.

All in all, it seems that the most important factor in the Egyptian environment is the Egyptian *farmer*, himself. No amount of engineering to increase production will permanently improve the economic status of the native as long as the great mass of people persist in breeding up to the extreme margin of subsistence. Every such increase in food supply in the past has been promptly followed by an increase in the number of mouths to be fed. Neglecting to recognize the *human* factor in the equation has simply resulted in a vicious circle and no progress.

FINGERS FOR EYES

THE STORY OF RAISED PRINT

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THERE seems always to have been among civilized peoples at least a vague realization that the finger should serve as the eye of the blind. We are told that the Egyptians developed a system of knotted strings, the size and relative position of the knots denoting different characters. By passing such a string through his fingers the blind person could decipher words, but it is perhaps questionable how much real reading was done in this way.

The famous Greek poet, Homer, is said to have been blind, and blindness must have been common under the Roman Empire. It is doubtful, however, if either the Greeks or Romans developed anything which could be called a system of reading for the blind.

As might naturally be expected, the Middle Ages saw practically no progress toward the development of devices for tactual reading, but after the Renaissance scattered attempts at the solution of this problem began to appear. During the sixteenth century Lucas in Spain and Rampazetto in Italy cut letters from wood which they were able to recognize by touch, and thus became familiar with the alphabet. Other blind individuals who attained fame as scholars worked out methods of tactual notation to meet their particular needs. For instance, in 1729 Nicholas Sanderson, the celebrated blind professor of mathematics at Cambridge University, developed a tangible system of mathematical computation.

Perhaps the nearest approach to a general system of raised print appeared about the middle of the seventeenth century in both France and Germany. This was the casting of individual movable metal type made either from lead or from tin. These, it was claimed, were readily recognizable by touch and could be arranged to form words, sentences and, in fact, any amount of literature, limited only by the number of type available. This idea, however, was far from being widely adopted, and it is no exaggeration to say that up to the end of the eighteenth century no satisfactory system had been developed to enable the blind to read with their fingers.

Like so many other important discoveries the idea of embossing tangible letters upon paper came about accidentally. Valentin Haüy, a young Frenchman, had been deeply impressed with the miserable lot of the blind of the late eighteenth century. Through his efforts the first school for the blind in the world was opened in Paris in 1784. The task of educating blind children with no means of teaching them to read must have seemed a colossal one, yet Haüy set about it undaunted.

On a memorable day in 1786 one of Haüy's pupils happened to handle some printed sheets which had just come fresh from the press. He noticed that he could decipher an "O" on the reverse side of the sheet produced by the pressure of the type on the "right side" of the paper. He called this to his teacher's attention and Haüy at once seized upon the idea as the long-sought solution of the problem of educating the blind.

It was a comparatively simple matter to set type so that embossed characters in correct sequence could be produced, and the production of books for the blind began. Haüy at first employed the italic or script type which was in common use at that time, including both capital and lower case letters (see Fig. 1). He indulged, however, in a wide variety of trial and error experimentation, including the variation of the size of characters from very small to very large, and also

the use of practically every kind of type known at the time.

Two theories dominated Haüy's experiments in the field of raised print. The first of these was that the blind must be educated through means identical with those for the seeing but translated into a tactual medium. Thus, he believed that a system of tangible print must be essentially the same as the print used for visual reading. This is shown by his insistence upon the use of both capital and lower case letters and in his relatively strict adherence to regular type form. His second theory was that a positive relationship existed between size and tangibility. That is, the larger the size of the letter the more easily it could be recognized by touch. Both of these theories have proved to be erroneous, yet the first one especially dominated the education of the blind for many years and, as we shall see, its influence is still to be found. Nevertheless, Haüy has been rightly called the "father of the education of the blind" since his discovery, accidental though it was, really marked the beginning of genuine education for those without sight.

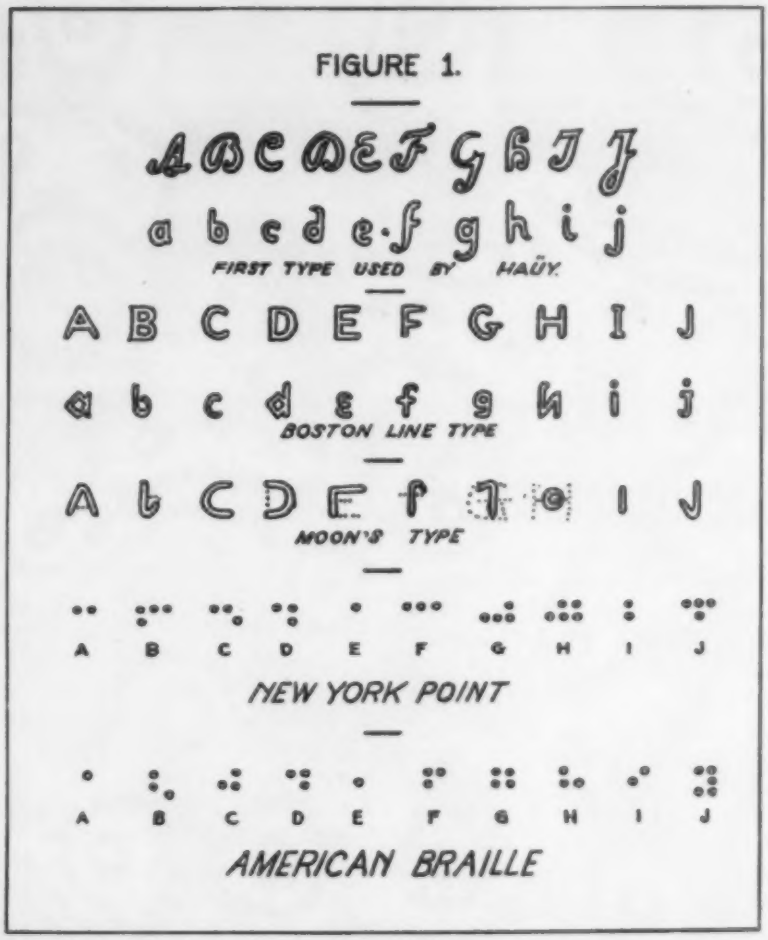
The work of Haüy in France stimulated similar efforts in England and in Germany. After various experiments a more or less modified Roman type was quite widely adopted. James Gall, of Edinburgh, developed a type based on the Roman forms, but with curved lines eliminated, believing that sharp corners increased tangibility. In Germany attempts were made to heighten tactual legibility by outlining the letters in dots or in serrated form. It is of interest to note here the inception of the idea that dots can be more easily recognized by touch than can smooth embossed lines. The belief, however, that tangible print must parallel visual print, as already noted, prevented the development at this time of an arbitrary system of reading for the blind.

The first book in embossed print to be printed in the United States was brought out in Philadelphia in 1833. The type used was a modification of the Roman alphabet somewhat like a system which had been developed in England. It remained, however, for Dr. Samuel G. Howe, director of the Massachusetts Asylum for the Blind, incorporated in 1829, and which later became the Perkins Institution and Massachusetts School for the Blind, to develop the production of books for the blind in this country. After studying the types in general use abroad he introduced what became known as Boston line letter (see Fig. 1), and for about forty years books in this type formed the principal source of reading matter for the blind in the United States.

As the use of embossed print in the education of the blind both in America and abroad increased, the incontrovertible fact soon presented itself that only a relatively small proportion of the blind could master tactual reading to a degree which made it much more than a "stunt." It was realized that to decipher laboriously a letter or word, and to read with enjoyment and profit were two widely different things, and when the novelty of the idea of reading with the fingers had worn off the relatively small number of blind persons who really could read in the generally-accepted sense of the term was discouragingly small. This led to a search for embossed types of greater tangibility and, what is still more important, to a gradual realization that a strict adherence to standard alphabet forms probably was impossible.

It is singularly fitting that the second great contribution to finger reading came from the school which Haüy had founded. It is significant, also, that this second contribution was made by a blind man who knew from personal experience the difficulties involved in tactual reading. This man was Louis Braille, a pupil in the Paris institution for the blind, who in 1829 produced the system of embossed print which now bears his name (see Fig. 2). He had obtained his

FIGURE 1.



idea from Charles Barbier, who had been working on various point systems of codification, chiefly for military use and not with the specific purpose of developing a system of reading for the blind. Braille based his work upon the theory, already referred to, that the raised dot is superior in tangibility to the embossed line. His system is based upon a "cell" of six points, three points high and two wide. Letters and other signs are obtained by varying the number and position of the dots within the cell.

One feature of his system which Braille considered of great importance was the so-called "principle of logical sequence." According to this principle the first ten letters of the alphabet form the basis of all other letters and signs. Thus "k" is "a" with the addition of the lower left-hand dot in the cell, and so on. Since the French alphabet contains no "w," this letter was missing from Braille's original system. It was introduced later to meet the needs of other languages and, as will be seen, is a "j" with the addition of the lower right-hand dot in the cell (consult Fig. 2). As will be pointed out later this principle of logical sequence has proved to be of no significance whatever, either in learning to read Braille or in writing it. This leads us to the second and most important contribution of Braille, that is, his system could be written easily by the blind through the use of a specially-constructed slate and stylus. Nothing of this kind had been possible with previously-developed systems of embossed print.

FIGURE 2.

STANDARD ENGLISH BRAILLE

With the many real and apparent advantages of the Braille system one would expect that it would have received immediate and wide-spread adoption. Such, however, was not the case. It was not used in the Paris school until 1834, found its way to England and Germany much later, and did not make its way to the United States until 1860 when it was introduced into the Missouri School for the Blind. The slowness of its progress can be attributed mainly to the persistence of the fallacy that an arbitrary system of reading for the blind was undesirable.

Another factor which undoubtedly hindered the spread of Braille's system was the invention in 1847 by Dr. William Moon, of Brighton, England, of a semi-arbitrary system of raised print, which has since been known as Moon Type (see Fig. 1). In this system the characters are based upon alphabetical symbols but are greatly simplified, and in some instances, purely arbitrary signs are used. Moon Type formed a half-way station between strict adherence to the visual alphabet and the wholly arbitrary system of Braille. It proved much more tangible than any of the "line-letter" systems in vogue at that time, and has been the only embossed type besides Braille to survive to the present day. It is supposed to be particularly well adapted for those who lose their sight late in life, although, as will be pointed out later, the reason commonly advanced for this is without scientific foundation.

American educators of the blind seemed to feel that the Braille system as originally worked out by its inventor could be made more efficient by certain modifications. The most important of these were New York Point (1868) and American Braille (1868) (see Fig. 1). New York Point, so called because of its

invention and promotion by the New York Institute for the Education of the Blind, literally laid the cell on its side, making it two dots high and three wide. By varying the number of dots, especially in the base line, a large number of combinations was possible. The principle of logical sequence on which Braille had put so much stress was abandoned in favor of the principle of frequency of recurrence, by which the smallest number of dots was assigned to the most frequently used letters. This, it was argued, resulted in greater speed of reading and writing.

American Braille, developed at the Perkins Institution, retained the original Braille cell of three dots high and two wide, but used the principle of frequency of recurrence, as can be seen by comparing the sample of American Braille in Fig. 1 with the Standard English Braille of Fig. 2.

By the beginning of the twentieth century the embossed type situation in this country was so chaotic that a committee was appointed by the American Association of Workers for the Blind to investigate the merits of each system and to recommend the adoption of one system for general use. In 1915 this committee, known as the Uniform Type Committee, reported in favor of Standard Dot, a system embodying the seemingly best features of New York Point, American Braille and Braille as originally invented. It was felt, however, that the production of a wholly new system would tend to complicate matters still further, especially since England had adopted the original Braille system, as had Germany and other European countries. The American aim was to agree upon a system which also would be acceptable to the English, and thus make the interchange of embossed books in the English language a comparatively simple matter.

The English had worked out a system known as British Braille Grade 2, which included the original Braille alphabet and a large number of contractions and abbreviations, and word and part-word signs which assist in saving space.

The objection was raised in America that these contractions and abbreviations were too complicated, that they frequently violated the principles of standard literary practice such as syllabication, etc., and were inimical to the teaching of spelling. After considerable discussion a compromise system, known as Revised Braille Grade One and a Half, finally was adopted in this country in 1916–17. This system was fundamentally the same as British Braille, except that about half the contractions in the latter were omitted and certain new rules as to capitalization, punctuation and paragraphing were followed.

This arrangement continued until 1932, when Standard English Braille Grade 2 was adopted both by England and the United States. It represents a practical return to British Braille, except for a few minor details. At last, therefore, after approximately a century of arguing, the system invented by the blind pupil of the school founded by the "father of the education of the blind" came into its own. It is now practically the only embossed type used throughout the entire world with necessary adaptation to meet the needs of various languages.

As one reviews the history of raised print, one is struck principally by the fact that no genuinely scientific approach has been made to the problems involved in tactual reading. Attempts to study the psychology of finger-reading have been few and scattered, those of Karl Bürklen[1] probably being of most significance. Many of the chief arguments for and against certain kinds of type have been based upon assumptions which never were proved experimentally.

[1] Karl Bürklen, "Touch Reading of the Blind" (translated by F. K. Merry), American Foundation for the Blind, Inc., New York, N. Y. 1932. Part I only.

The old fallacy of Haüy that what looked well to the eye must also be suitable to the finger has been responsible for many errors in this field.

For example, Bürklen has shown that there is no relationship whatever between the number of dots in a Braille character and the ease with which it is tactually perceived. The basis of perception, rather, seems to be in the shape of the character, and since Braille consists of a relatively small number of simple forms, confusion between them is responsible for reading difficulty, rather than variations in the number of dots. Reference to Fig. 2 will illustrate this point. For instance, "A" and "G" are essentially block forms, "E" and "I" are diagonal line forms, "D," "F," "H" and "J" are corner forms, while "B" and "C" represent vertical and horizontal line forms, respectively. Other letters and signs are simply expansions or combinations of these fundamental forms. This destroys the main argument advanced by the proponents of New York Point and American Braille, that is, that characters with the fewest dots are easiest to read, hence the most frequently recurring characters should have fewer dots than those used less often. It also vitiates Braille's theory of logical sequence, that is, building the alphabet upon ten simple characters.

The statement so often heard that Moon Type is better suited to the needs of older persons, whose fingers are calloused and whose sense of touch is duller, is hardly consistent with the generally recognized fact that the dot is more tangible than the embossed line. In so far as we can credit data obtained through introspection, the real reason why Moon Type often is learned more easily by older persons has nothing to do with the condition of their fingers. An individual losing sight late in life still retains visual imagery, and all indications point to the fact that tactual sensations are translated into visual images in the process of perception. This rendition of tactual sensations into visual images is, naturally, easier when the tactual materials are closely allied to what the individual has known in visual experience than when the materials are entirely different. As has been shown, Moon Type bears a close resemblance to the visual alphabet, while Braille is entirely arbitrary, hence the person learning to read by touch would find it easier to attach meaning to symbols whose visual images corresponded closely to those with which he had once been familiar rather than to images of symbols which are entirely unfamiliar to him. The dulling of tactual sensitivity through callouses, etc., is to be doubted, since finger-readers of many years have reported that a fairly hard callous develops on the tip of their reading finger without in any way appearing to lessen its sensitiveness. Some individuals, also, can read through several thicknesses of cloth or even with gloves on.

Another fallacious argument has been that the use of contractions and abbreviations decreased the individual's ability to appreciate the material read, or resulted in poor spelling. Such investigations as have been made indicate that not only are Braille letters perceived as wholes, regardless of the number of dots contained therein, but also that entire words are perceived as wholes. Thus, the use of contractions has none of the harmful effects claimed for it, but, on the other hand, increases the speed and thus adds to the enjoyment of finger reading.

Other factors in tactual reading not well understood are the relation of movement to the perception of embossed characters and words; the best size of the Braille cell; the best height of dot and many others. In relation to the first of these it may be pointed out that the essential difference between finger and eye reading is that the former takes place only when the finger is moving over the characters, while the latter occurs during

the pauses made by the eye in traveling along the line. Bürklen studied touch movements to some extent, but, as he himself admits, his apparatus was too crude to permit of any very definite conclusions. The use of the moving picture camera in studying this phase of touch reading undoubtedly would give us much valuable information. The relation of pressure to movement in the process of finger reading is also a problem needing investigation. Bürklen found that in general greater pressure is exerted by poor readers, and these, also, make more random movements.

The customary size of the Braille cell is about 7 mm high and 4.5 mm wide. There is no experimental proof to show that this is the best size to use. In fact, there are indications that a smaller cell would not only save space, but also would increase facility of reading. The problem of space is an important one in embossed printing. For example, the ordinary ink-print edition of a certain book measures $8\frac{3}{4} \times 6$ inches with a thickness of about $\frac{7}{8}$ of an inch. Its cubical contents are roughly 46 cubic inches, and it contains 243 pages of 11-point type. The Braille edition of this same book comprises three volumes 11×11 inches and about $2\frac{1}{2}$ inches thick each. The total number of pages in the three volumes is 547 and their total cubical contents are $877\frac{1}{4}$ cubic inches. Thus we see that in this case the Braille book is a little more than 19 times the size of its inkprint counterpart.

One of the most persistent beliefs founded upon the false analogy between tactual and visual perception is in relation to embossed pictures and diagrams. Investigations have shown with a fair degree of conclusiveness that such pictures and diagrams are practically meaningless to the finger-reader, yet printers of Braille books continue to include them at considerable labor and expense.

The foregoing indicate only a few of the many problems related to tactual reading which require scientific investigation. Raised print has been developed very largely by trial-and-error methods, due probably, in part, to the lack of scientific training of those engaged in this field of work and in part to the relatively small number of finger readers as compared to eye readers. Nevertheless, the production of embossed literature in the United States alone has grown to no mean proportions during recent years. Hundreds of Braille volumes are printed annually and more than forty periodicals, including a weekly newspaper, appear regularly. The Federal Government appropriates each year a total of one hundred and seventy-five thousand dollars to aid in the printing of books, and while this is insignificant when compared with huge appropriations for other purposes, it is large enough to merit an effort to spend it to the best possible advantage. The question is being raised at present whether the newly developed "Talking Book," which embodies the principle of recording books upon long-playing phonograph disks, will not eventually eliminate tactual reading. While it is difficult to predict what will happen in this regard, it seems unlikely that the "Talking Book" will ever supplant Braille, although it will constitute a valuable supplement to it. When it is realized that still only about one half of the estimated one hundred thousand blind persons in the United States can read with their fingers, there would seem to be plenty of room for both Braille and the "Talking Book."

The psychology and physiology of tactual reading are almost untouched fields of investigation, and it is to be deeply regretted that facilities for this type of study are so limited. Those who are seeking new fields to conquer in psychological research will do well to turn their attention to this subject, where they may not only discover significant facts concerning the psychology of tactual perception, but also may render important contributions to the practical problems of Braille printing.

FALSE GROUP THEORY

By Professor G. A. MILLER
DEPARTMENT OF MATHEMATICS, UNIVERSITY OF ILLINOIS

For many years there has existed a false group theory which has increasingly hindered the effectiveness of the true theory relating to this subject. Some of the most noted mathematicians have contributed towards the spreading of this false theory, as may be seen from a note to F. Klein's now famous "Erlanger Programm" published in the *Mathematische Annalen* (Vol. 43, 1893, page 66), in which it is explicitly stated that a group need not contain the inverse of each of its operators, and S. Lie is here said to have been the first to point out that the existence of the inverse of each operator is not a consequence of the group concept as such when the order of the group is infinite. The group concept was first formulated as a result of the study of ordinary substitutions (permutations) and these obey intrinsically all the postulates of a group except the one which asserts that the set of elements under consideration must have the property that the product of every two of them and the square of every one is found in the set. Hence this postulate alone was somewhat naturally assumed by some of the early workers in this field to embody the complete group concept instead of being only one of the essentials of this concept.

Various terms commonly employed in the mathematical literature, such as algebra and geometry, are used without a clear definition, and this use causes little inconvenience since special subjects of these broad fields are commonly under consideration and it frequently makes no difference whether these special subjects are regarded as algebra or as geometry, but with respect to group theory the case is quite different, since the term group implies a definite concept which has led to an abstract theory of great importance. The development of this abstract theory is based directly on the definition of this concept and would have been entirely impossible if other definitions frequently employed had been substituted for the exact definition. Hence it follows that those who employ a partial definition of the term group convey the impression that they are working along the lines of an important abstract theory which often has very little in common with what they are doing and could not have been developed even partially if the definition used by them had been employed.

A postulate of the group concept which may be regarded as next in importance to the one noted in the first paragraph of the present article is that the elements of a group must obey the associative law when three or more are combined, two at a time, into one. The history of this law in the mathematical literature is very interesting, since it involves a fundamental feature of the history of mathematics as a whole, *viz.*, the remarkable slowness with which some abstract ideas entered into the general literature of our subject. This law seems to have been first given a special name by the most noted Irish mathematician up to the present time, *viz.*, W. R. Hamilton (1805–1865), who is most widely known now on account of his discovery of quaternions in 1843, and whose collected "Mathematical Papers" began to appear in 1931. He seems also to have been the first to emphasize the great importance of the associative law in various mathematical subjects, but A. Cayley (1821–1895) was the first to employ it explicitly in a definition of the term group. He did this in his

first article on group theory which was published in 1854 in the *Philosophical Magazine*.

It is a striking fact that A. Cayley did not continue to include the associative law in his later definitions of the term group. His failure to recognize the fundamental and abiding importance of this law is reflected in the definition of the term group in the recently completed "Oxford English Dictionary" in eleven volumes (1888–1933), which does not refer to this postulate and thus contributed powerfully to the spread of a false group theory among the English-speaking peoples. The lack of clarity along this line is also exhibited in the recent second edition of Webster's "New International Dictionary," since the associate postulate was explicitly noted in the earlier edition of this work but was omitted under the entry of "group" in this second edition (1934). There is, however, an entry in this edition entitled "associative law" under which it is stated that it is a fundamental law of group theory, but nothing is said about the fact that it constitutes a fundamental element of the term group in all the treatises devoted to the theory of abstract groups and is an essential part of the definition of abstract group as employed in these treatises.

It should not be inferred that the English speaking people are the only ones who have been largely led astray by a false group theory which tends to becloud the beginners who are impressed by the many enthusiastic remarks relating to the usefulness of the concept of group in nearly all branches of mathematics, including the most elementary ones. In fact, the present article was inspired mainly by a recent French publication entitled "Premières leçons sur la théorie générale des groupes" by Georges Bouligand, who published about a hundred articles relating to mathematics in important French periodicals during the last quarter of a century and exhibited therein a wide acquaintance with the modern mathematical literature. On page 5 of this volume of 242 pages it is claimed that a group is associated with every mathematical proposition, *viz.*, the group composed of all the modifications of this proposition which lead from one case of exactitude to a new case of exactitude. It is stated on the same page that an illustration of such modifications is furnished when the so-called Pythagorean theorem relating to the squares on the three sides of a right triangle is modified by replacing these three squares by three similar figures which are similarly placed with respect to this triangle.

One of the reviewers of this volume aptly remarked that Professor Bouligand had exhibited therein anew that he was able to wear the mantle of Felix Klein and other reviewers exhibited their delight in following the views expressed therein. The student of group theory may, however, be led to observe that if all these modifications constitute groups what is left of his beloved subject? A theory of abstract groups could certainly not have been developed if all these modifications were to constitute a part thereof. Is it right that those who apparently know practically nothing about this abstract theory should be allowed to dignify their work by a name belonging to a subject which gained a wide reputation by legitimately restricting itself to domains of relatively small extent but of fundamental importance? It must be admitted that much progress in mathematics has been made by calling different things by the same name and it might be argued that some of the most noted names in the history of group theory, such as those of C. Jordan, F. Klein, S. Lie, and H. Poincaré, are those of men who never formulated in their work a definition of the term group which could be used as a basis for an abstract theory of this subject. These men were interested mainly in the applications of group

theory and the subjects which engaged their attention primarily involved intrinsically elements which had to be explicity embodied in an abstract theory of the subject.

What deserves especial emphasis in this connection is that the properties inherent in subjects to which mathematics has been applied have sometimes greatly affected the definitions of mathematical terms. Such affected definitions may be very useful while working on these subjects in view of their peculiar bend, but they are naturally of little value when applied to some other subjects or when they are used with respect to an abstract theory. It might be asserted that if men like Archimedes, Descartes and Newton could do such effective work in mathematics without a knowledge of the associate law in the combination of operations it might be questionable whether the students in our modern schools should be compelled to familiarize themselves with this law, and whether writers of elementary text-books should be criticized for not referring to this law in their effort to popularize group theory in elementary mathematics. A partial answer to this question is furnished by the fact that the modern student of mathematics is taught from the beginning to be more circumspect than his predecessors were and that he is taught early to avoid some of the loopholes which affected adversely some of the work of preceding generations.

It is well known that modern mathematicians experience great difficulties in their efforts to understand each other as a result of the great variety of subjects which have become objects of mathematical invesigation and the diversity of the methods employed therein. Many of these difficulties are a natural result of the remarkable increase in the number of mathematical investigators and the competition engendered by the desire to attain positions of influence and to master difficulties to which wide attention has been directed especially as a result of the rapidly increasing number of periodicals devoted to this subject. It is therefore very desirable that these difficulties should not be augmented unnecessarily by the use of terms with widely different meanings. For instance, there seems to be no good reason why the student of this subject should find in one place, as on page 130 of the volume cited above, the statement that the positive integers with the exception of zero constitute a group when they are combined by multiplication, while he finds in various other places the contrary statement that they do not constitute a group because they do not include the inverses of the operations involved therein.

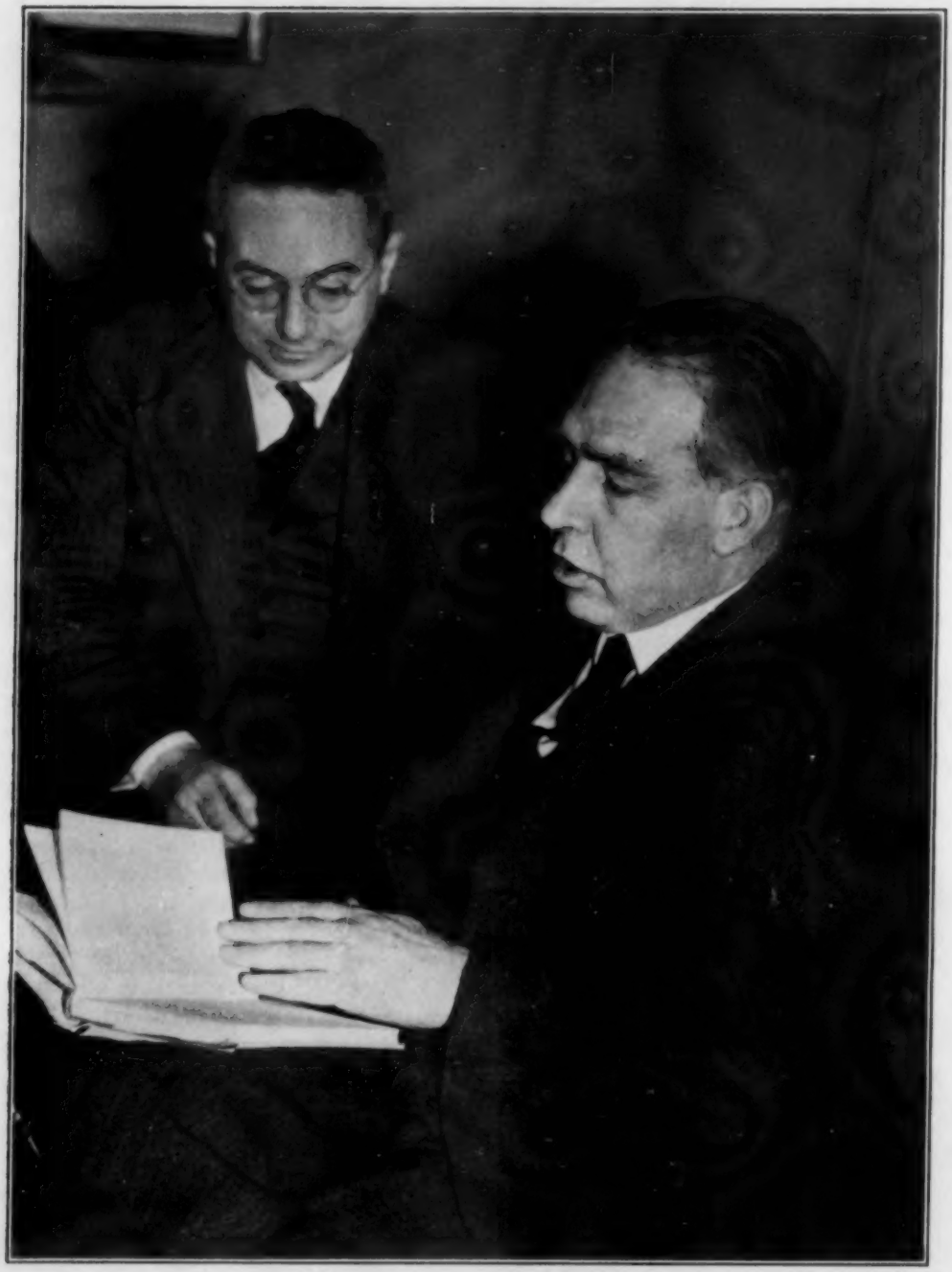
The group postulates to which we referred above are represented by the following continued equation: $(x\ y)z = x(y\ z) = x\ y\ z$. This expresses the fact that every two elements can be combined into one, that the associative law is satisfied when three or more are thus combined, and that only two of them can be combined at the same time. If more than two could be combined at the same time new possibilities would present themselves. For instance, it might be assumed that a product would be affected by the number of the elements which would be combined at the same time. This fact has not been sufficiently emphasized in the treaties on group theory but is obviously of paramount importance in an abstract theory of groups. To complete the group postulates it is only necessary to add that when two of the symbols of the equation $x\ y = z$ are replaced either by two elements of the set or by the same element of the set then the resulting equation has always one and only one solution with respect to the elements of the set. A number of other equivalent formulations of the group postulates have been given and it is to be expected that there is no general agreement as regards the

best formulation. The applications in view naturally affect the choice as regards wording.

The necessary and sufficient group postulates noted in the preceding paragraph are somewhat exacting and naturally do not appeal to the hasty student who takes little time to reflect on the implications in the various assertions with which he is confronted. A large number of the mathematical operations with which the student becomes acquainted early in his career do not obey all these postulates and it is simply absurd to say that all the modifications of a mathematical proposition which lead from one case of exactitude to a new case of exactitude constitute a group. There are however, also many instances of modifications, such as the permutations of the letters in an expression which do not alter the formal value of this expression. These obey all the given postulates and hence they constitute a group. Such modifications present a rich and fertile field for group theory and it is here where group theory exhibited its wide usefulness long before a formulation of an abstract group was attempted.

There is a wide difference between the popularization of a subject and the popularization of the name of a subject. Efforts along the former line imply a familiarity with the essential features of the subject and hence have educational value, while efforts along the latter line may tend to obscure these features and hence to misconceptions in regard to the real nature of the subject. Researches relating to the modifications of propositions within the range of exactitude are of great value to the student of mathematics, but real progress along this line implies a classification of these modifications with respect to their essential differences and not a lumping of them under a name which applies properly to only a small part of them. The unlearning of misinformation is already an undue burden on the student, and this burden should not be increased by misnomers relating to the more advanced subjects. Such platitudes could not be justified here if the subject to which they relate were not of unusual scientific interest.

Some mathematical readers of this article may be inclined to say that when they desire information in regard to the correct definition of a mathematical term they do not consult one of the large dictionaries noted above, which are objects of just pride on the part of English and American scholars, respectively, but they consult the mathematical works employing these terms. One may, however, be justified in insisting that one should not find misinformation in these dictionaries and in works especially intended for teachers of elementary mathematics as the volume cited above in the fifth paragraph of this article. These facts seem to justify a vigorous protest and an effort to exhibit clearly their adverse tendencies. It may also be of interest to the student of general science to see that in such an exact science as mathematics false gods have sometimes been set up and many have been misled to worship them.



PROFESSOR NIELS BOHR

TO THE LEFT IS PROFESSOR RICHARD COURANT, CHAIRMAN OF THE DEPARTMENT OF MATHEMATICS IN THE GRADUATE SCHOOL OF NEW YORK UNIVERSITY.

THE PROGRESS OF SCIENCE

PROFESSOR BOHR'S VISIT TO AMERICA

PROFESSOR NIELS BOHR, director of the Institute of Theoretical Physics at Copenhagen, will give the Hitchcock lectures at the University of California at Berkeley during the month of March. He will give a series of public lectures and will hold daily conferences and colloquia. The Hitchcock professorship, endowed by the late Charles M. Hitchcock and his daughter with the sum of $120,000, has been held by a number of distinguished foreign and American scientific men.

On his way to California Professor Bohr gave the first of a series of lectures at American and Canadian universities on January 29 at Washington Square College, New York University, where he discussed "The Problem of Causality." Professor Bohr was introduced by Professor Richard Courant, chairman of the department of mathematics in the Graduate School of the university, who was Professor Bohr's host at a tea in his honor preceding the lecture. The address on "The Structure of Nuclei" which was to be given on the previous day was cancelled because his arrival in New York with Mrs. Bohr and their son Hans on the *Aquitania* was delayed more than a day by a stormy crossing.

Among other institutions which have invited Professor Bohr to deliver one or more lectures during his present visit are Columbia University, the Institute for Advanced Study at Princeton, Harvard University, the University of Toronto, the University of Rochester, Duke University, the Johns Hopkins University, the Carnegie Institute of Technology and the University of Michigan. After serving as Hitchcock professor at the University of California Professor Bohr will lecture at universities in Japan and China on his way back to Europe.

There is hardly a physicist who has exerted a deeper and more constant influence in the development of the physical sciences during the last twenty-five years than Professor Bohr. The great progress in our understanding of the physical behavior of the elements, the periodic system, radiation, photochemical processes and many other things bearing on the structure of matter is definitely linked to the so-called Theory of Quanta. And the whole quantum theory, after Planck's discovery of the quantum of action, has developed under the leadership of Professor Bohr.

Bohr's atomic model of 1912 was only the start. It solved the problem of the spectrum of hydrogen. Soon Bohr's ideas also led to an understanding of the spectra of the other elements; since then theoretical and experimental physics and physical chemistry have been revolutionized on the basis of the quantum theory.

The progress that has been made in this short interval is unequalled in the history of physics. Scientific men of first rank all over the world have participated in the task of investigating the construction of matter and radiation, and recently in particular the construction of atomic nuclei. The Institute of Theoretical Physics at Copenhagen under the direction of Professor Bohr has been responsible for much of the work.

One of the most significant features in the development of the quantum theory, Heisenberg's principle of indetermination, was also developed in this institute. It has become in the hands of Bohr the start for a general philosophical point of view, which can be applied to other fields of human knowledge as well as to physics. These general aspects have led to a limitation in the applicability of the

principle of causality, and are pointing to a similarity between certain principles underlying quantum physics and fundamental phenomena in psychology and biology. This new point of view, called the principle of complementarity, dispels the contradictions which arise in the field of atomic phenomena, and throws light on fundamental questions of psychology and biology.

Born in Copenhagen in 1885, Professor Bohr received his Ph.D. in 1911 at the University of Copenhagen, where he has been since 1916 professor of theoretical physics. He was lecturer at Copenhagen in 1913 and at the University of Manchester from 1914 to 1916. He was awarded the Nobel Prize in 1922; a year earlier he received the Hughes Medal of the Royal Society, London, and was elected a member in 1926. Professor Bohr was made a foreign associate of the National Academy of Sciences in 1925 and is a member of many other national academies.

H. S.

THE PERMANENT SECRETARY OF THE AMERICAN ASSOCIATION, ELECTED AT THE RECENT MEETING

THE American Association for the Advancement of Science has elected as its permanent secretary a distinguished mathematician and astronomer, Dr. F. R. Moulton. It is understood that he will reside in Washington after May 1 and devote his entire time to the work of the association. Dr. Moulton has been long interested in the association, having been a vice-president for astronomy and a member of the executive committee. He has been president of Sigma Xi and a member of the executive council; he is a member of the National Academy of Sciences, having been elected at the age of thirty-eight, the American Philosophical Society and the American Academy of Arts and Sciences, as well as of the Astronomical Society of America, the American Mathematical Society and other American and foreign societies.

Moulton was born at LeRoy, Michigan, in 1872. Shortly after his graduation from Albion College in 1894, he went to the then very youthful University of Chicago and received his doctor's degree, *summa cum laude,* in 1899, his work being in the field of mathematical astronomy. For nearly thirty years thereafter he was a member of the faculty of the University of Chicago, serving through the various ranks to a professorship in 1912. There he had as his associates the distinguished scientific men brought to Chicago by President Harper who included Michelson, Millikan, Moore, Stieglitz, Chamberlin, Whitman, Williston, Hektoen, Jordan, Donaldson, Loeb, Coulter and Dewey.

In addition to many contributions of a purely mathematical character, Moulton explored, in cooperation with his students, the method of periodic solutions of the differential equations of mechanics —a method which was originated by the American astronomer George W. Hill in his theory of the motion of the moon. Hill's method of treating this particular problem was appreciated by the French mathematician, Henri Poincaré, who, bringing to the problem an unrivaled mastery of modern mathematical analysis, generalized and extended Hill's method to a wide class of problems in mechanics. Moulton's work in this field culminated in his classification of the periodic orbits, in the problem of three bodies and in the demonstration of the existence of certain limiting orbits which he called orbits of collision and ejection. His work in this field, together with the work of some of his students, will be found in a large volume, "Periodic Orbits," published by the Carnegie Institution of Washington (1920).

But the work for which Moulton is most widely known is his development, in collaboration with the late Professor

DR. F. R. MOULTON

T. C. Chamberlin, of a theory of the origin of the solar system, of planets and their satellites—a theory that is known as the planetesimal hypothesis. According to this hypothesis the origin of the sun's family of planets is to be found in the circumstances attending a close approach to the sun of some star—a biparental theory, as Chamberlin called it, in contrast with the nebular hypothesis of Laplace, which sought the origin of the planets in the contraction of the sun due to loss of heat and a consequent excessive rate of rotation—a purely monoparental theory.

In 1918 Moulton was appointed major in the army and placed in charge of the ballistics section in the Ordnance Department at Washington. Here he quickly found that the theory of the trajectories of projectiles as developed and used by the armies of Europe was unsatisfactory to an astronomer, who was accustomed to much better methods in tracing out the paths of the planets in their flight about the sun. After all, a projectile is something like a little planet and in introducing astronomical methods into the theory of the motions of projectiles he was not departing very far

from his chosen field of celestial mechanics. After he had retired from the army with the rank of lieutenant-colonel and returned to the University of Chicago, a number of officers from both the army and the navy were sent to the university for several years to be trained by him in the theory of ballistics. Finally (1926) he published his work in this field in a volume entitled "New Methods in Exterior Ballistics."

In 1927 Moulton resigned his professorship and became a director of a large public utility corporation. Notwithstanding his duties in this new field he has found time to write a new text-book on astronomy (1929), a volume on differential equations (1931) and a popular work on astronomy under the title "Consider the Heavens" (1936). He is now contributing to and editing a book on the physical and biological sciences, and he gives weekly broadcasts on all the Columbia network except the northeastern stations.

From 1873 to 1937—a period of sixty-four years—the American Association had (apart from a short interregnum) but four permanent secretaries—Putnam, Howard, Livingston and Ward. They are all biologists. It is appropriate that they should be followed by a worker in the physical sciences distinguished for his contributions to mathematics, celestial mechanics and mathematical physics, with wide interests covering the whole field of science and organization for the advancement and diffusion of science.

A NEW INTERNATIONAL RADIO SERVICE FOR BROADCASTING COSMIC DATA

A NEW scientific journal, one that is issued by radio rather than with paper and ink, was inaugurated in Boston on February 1 when World Wide Broadcasting Foundation's short-wave station, W1XAL, began daily broadcasts of cosmic data and scientific news. The station in this activity cooperates with the Union Radio Scientifique International, familiarly known in scientific circles by its initials URSI, and Science Service, the institution for the popularization of science. Each afternoon W1XAL will announce in plain English technical data on observations of sunspots, solar radiation, magnetism, ionized layer heights and other phenomena that have been observed in far corners of the world during the same day. The primary purpose of these broadcasts is to make such information available internationally and to interest scientifically inclined laymen in the making of observations.

For nearly seven years Science Service, in cooperation with the American Section of the Union Radio Scientifique International, has collected and distributed daily information about these fundamental inconstants of nature. The Army Radio Net has brought some of this information to Washington, and the Navy has lent its valuable cooperation in the broadcasting of the daily cosmic data messages in international Morse code.

Through arrangements effected by Walter S. Lemmon, radio engineer, who is founder and president of the World Wide Broadcasting Foundation, the facilities of educational short-wave station W1XAL are made available for the extension of the ursigram service in cooperation with Science Service. This station, licensed for international broadcasting on four frequencies, now operates on 20,000 watts and is heard with good volume in almost all parts of the world. The broadcasts of cosmic data and scientific news should, therefore, be available to listeners anywhere who are suitably equipped with standard all-wave receivers. Mr. Lemmon stated this new radio service "will aid world wide cooperation in scientific observation and make more effective the correlation of cosmic causes and cosmic effects."

The Foundation is "dedicated to en-

AT THE INAUGURATION OF THE NEW BROADCASTING SERVICE

LEFT TO RIGHT: DR. HARLOW SHAPLEY, DIRECTOR OF HARVARD COLLEGE OBSERVATORY AND TRUSTEE OF WORLD WIDE BROADCASTING FOUNDATION; PROFESSOR A. E. KENNELLY OF THE ELECTRICAL ENGINEERING DEPARTMENT OF HARVARD UNIVERSITY AND CO-DISCOVERER OF THE KENNELLY-HEAVISIDE LAYER WHICH MAKES SHORTWAVE TRANSMISSION POSSIBLE; AND DR. LORING B. ANDREWS, AN ASTRONOMER AT THE HARVARD COLLEGE OBSERVATORY AND CHAIRMAN OF THE W1XAL PROGRAM DEPARTMENT.

lightenment," and in accord with this motto it broadcasts only educational programs, thus endeavoring to give its listeners a broader outlook, a better balanced life in which the deeper needs of mankind are supplied, and fostering international good-will and understanding.

A NEW HIGH VOLTAGE X-RAY PLANT FOR RESEARCH AND THE TREATMENT OF CANCER

A NEW type of x-ray apparatus has been erected at the Presbyterian Hospital in New York City in conjunction with the Institute of Cancer Research of Columbia University, thus combining two activities, the treatment of patients by the hospital and experimental work by the institute.

The design is due to Mr. David H. Sloan, of the University of California. A novel principle which underlies the construction of the apparatus is the use of powerful radiofrequency transmitting tubes to set up oscillations of some 50 meters wave-length in a single turn primary and then inducing in a closely coupled secondary of some 12 turns, extremely high voltages. When properly adjusted the power losses between the oscillator tubes and the anticathode output are so low that enormous amounts of x-ray can be generated. As the ratio between the primary and secondary coils is only 1 to 12, it is obvious that the ap-

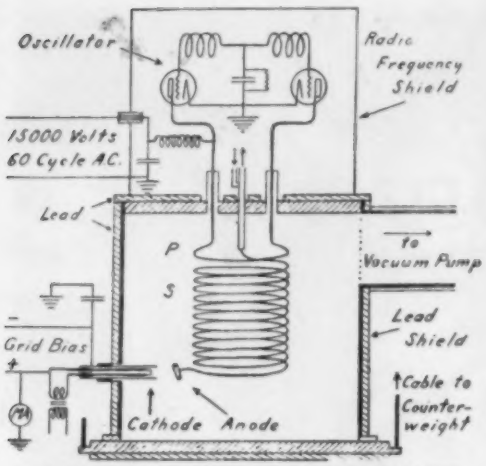
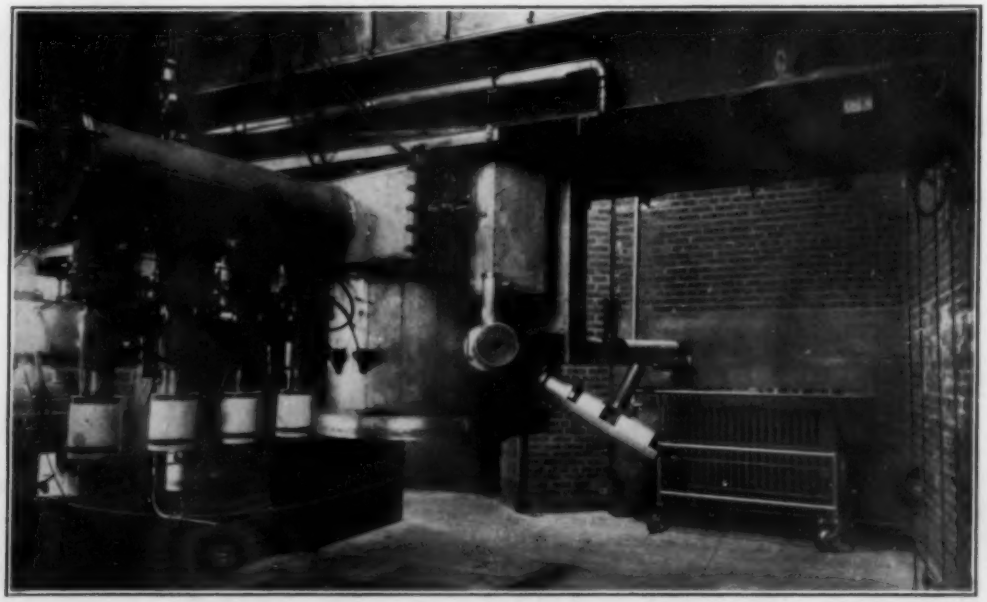


DIAGRAM OF X-RAY APPARATUS

paratus does not act as a simple transformer, but that there are also resonant oscillations between the different turns of the secondary which greatly amplify the voltage ratios between the antenna and the secondary coil.

The elimination of the intense heat produced is a limiting factor in machines of this type. Mr. Sloan believes that 5,000,000 volts could be obtained without difficulty with certain changes in the arrangement. Whether the production of x-rays at this voltage would be effective is a matter to be decided by experimentation. It may be that 5,000,000-volt electrons would busy themselves causing mutations in the tungsten atom rather than in inducing x-rays. As the tank and much of the apparatus are demountable for convenience of repair, occasional leaks may occur, and, unquestionably, despite the large amount of water used for cooling, a certain amount of evolution of occluded gas or of metallic sputtering must take place, especially if there is any arching between the turns of the secondary. To control these conditions powerful diffusion pumps are necessary, a special type of which has been designed by Mr. Sloan. The practical running of the apparatus in the last few months has demonstrated that the pumping system permits the production of an extremely high vacuum, amounting to something of the order of 10^{-6} mm, 1,000,000 volts.

The mechanical construction is relatively simple, as shown in the diagram taken from Mr. Sloan's paper in the



THE HIGH VOLTAGE X-RAY PLANT AT THE PRESBYTERIAN HOSPITAL

Physical Review, volume 47, 1935. It will be seen that the apparatus consists of a power source of about 15,000 volts, single phase, alternating current. This is fed into two generating oscillators of special design, the grids of which are coupled and develop powerful radiations in a short antenna of one turn of heavy copper tubing. The amount of energy which these oscillators must handle is considerable, being of the order of 10 kilowatts. This antenna is suspended in an evacuated stainless steel tank, in which is also hung the secondary, which consists of 12 turns of copper tubing. This carries the anticathode, and through it a large amount of water flows to absorb heat. A filament, which is biased so that only the peak of the wave is used, furnishes the electrons for the target.

The tank, which is swung from steel beams, has five portals, one pointing downward, which is to be used for experimental purposes, and four for the treatment of patients. It is covered with 4 inches of lead for protection from the x-rays.

PATIENT UNDER TREATMENT

The great advantage of the apparatus is, in the first place, its range of voltage, from 200,000 to 1,200,000 volts; secondly, the large current which can be used at the lower voltages. It is possible at 300 or 400 kv. to use 20 or 30 milliamperes, the only limit being the capacity of the water supply for cooling. Such capacity permits the administration of 500,000 Roentgen units through one half millimeter of copper, in a couple of hours, for experiments in which these enormous quantities are important. On the other hand, running at 1,200,000 volts, it will carry 2 milliamperes of current. At these voltages it is possible to see through 1½ inches of lead with the fluoroscope. Five mm or more of lead, therefore, can be used as a treatment filter, and under these circumstances the machine will give 5 Roentgen units per minute at a distance of some 5 feet from the anticathode. The treatment portals are conveniently arranged, as they contain a mirror which reflects the light of a small lamp through the opening in the heavy lead portals which define the x-ray beam. The light is so arranged that it covers the exact area which is to be exposed to x-ray. Thus during treatment the patient can be watched and the exact spot on which the x-ray is reaching the surface of the body controlled. It is proposed to use the machine, at first, to study the Coutard method of treatment with a low rate of radiation and prolonged exposures, obviously, only on selected material, for it is not necessary to use high voltages on superficial tumors.

FRANCIS C. WOOD

THE EFFECT OF EDUCATION ON THE I. Q. OF IDENTICAL TWINS REARED APART

R. C. CATTELL, in a recent article in *The Eugenic Review*, states categorically "that mental capacity is inherited, but that character, habits and skills are largely a matter of the environment." Holzinger in 1929 came to the conclusion from a study of twins that nature and nurture factors have approximately equal influence in determining I.Q. differences. Thus we see that opinions as to the relative potencies of hereditary and environmental factors in determining mental differences vary widely. It is hoped that our study of twenty cases of identical twins separated in infancy will throw some light on this old problem.

The detailed life histories of these twenty cases were analyzed and rated by five independent judges. Their environmental differences were rated numerically from 0 to 10 points, with reference to three categories: educational, social and physical-health. The ratings in all three showed over 90 per cent. agreement for the five judges. These rated environmental differences were then correlated with all measured mental, temperamental and physical differences between individuals of twin pairs. Only seven correlations were high and statistically significant. Five of these were between educational differences and differences in various mental test scores, three between social differences (of a cultural sort) and mental test scores, and one between physical-health differences and differences in body weight. Hence practically the only significant correlations between environmental variance and measured characters concerned mental differences.

The correlations between differences in educational and mental test scores differences were as follows: Binet I.Q., 0.791; Otis I.Q., 0.547; International, 0.462; American Council, 0.57; and Stanford Achievement, 0.908. The correlations between differences in social environment and mental test score differences were as follows: Binet I.Q., 0.507; Otis, 0.533; and International, 0.534. The highest correlations occur in those tests that involve acquisition of knowledge, but the correlation for the International Test, a non-language test, is not much lower than for the Otis test.

It should be noted, however, that most of the positive correlation is produced by a few cases in which the educational difference was great. Without these five cases the correlation is greatly lowered. In fact, if we omit five of the cases having the largest differences in education, the average difference in I.Q. of the remaining fifteen pairs of identical twins reared apart does not exceed that of identical twins reared together.

From this study we may conclude that the I.Q., whatever this may measure, is definitely modified by large differences in education, both of the formal and informal sort. It seems equally justifiable to conclude that small educational differences of one to three years schooling and small differences in social environment do not significantly affect the I.Q.

It is possible with our materials to go one step further and to determine what are the approximate contributions of the different environmental factors in producing the variance in I.Q. in these twins reared apart. Assuming that the influence of a factor on a character is in proportion to the amount of correlation between them, we have calculated for the Binet I.Q. that:

50 per cent. is attributable to educational differences.

10 per cent. is attributable to social differences.

12 per cent. is attributed to joint educational and social differences.

9 per cent. is attributable to physical-health differences.

19 per cent. is attributable to unknown factors.

Similar shares of environmental influence have been worked out for other

mental tests. The detailed report of these studies is now in press and will soon be published by the University of Chicago Press, under the title, "Twins: and the Problems of Heredity and Environment." by H. H. Newman, F. N. Freeman and K. J. Holzinger.

H. H. NEWMAN

ON THE CAUSE OF INFLUENZA

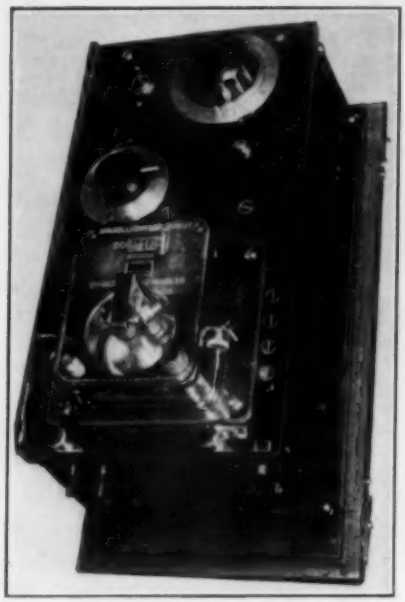
FROM the time of Pfeiffer's discovery of *H. influenzae* in 1892 until the 1918 pandemic, this organism was generally considered the cause of influenza. Work done during and following the 1918 pandemic with *H. influenzae,* however, cast doubt on its causative significance. Evidence was advanced by some investigators at this time that the disease was caused by a filtrable virus. Others, however, were unable to demonstrate that a virus was involved. The question as to the etiology of influenza was, following the work done during the 1918 pandemic, highly controversial.

A disease of swine which appeared supposedly for the first time in 1918 and which because of its marked similarity to human influenza was called "swine influenza," was studied at the Rockefeller Institute, Princeton, N. J., by the late Dr. Paul Lewis and by Dr. R. E. Shope. These investigators found that this disease had a complex etiology; that is, it was produced by the concerted activity of two agents. One of these was a bacterium, similar in all respects to Pfeiffer's *H. influenzae,* the other was a filtrable virus different from any previously encountered. This work suggested the possibility that human influenza might have a similar complex etiology. The thing lacking, so far as the human disease was concerned, was the definite demonstration of a filtrable virus. There was not long to wait for this. In 1933, Dr. Wilson Smith, Dr. C. H. Andrewes and Sir Patrick Laidlaw, working at the National Institute for Medical Research in London, demonstrated that the filtered nose and throat washings from cases of human influenza contained a virus which was capable of infecting ferrets and mice. Other strains of an identical virus were isolated by Dr. Thomas Francis, Jr., of the Rockefeller Institute, from cases of the disease in Puerto Rico and Philadelphia. This new human virus and swine influenza virus were found to cause identical disease pictures in ferrets and mice. The two agents were, however, serologically different. Evidence obtained in neutralization experiments with human sera suggested that the human virus was a wide-spread infectious agent. They further demonstrated that the swine virus had also, at some time in the past, infected man. The theory has been advanced that the swine virus may represent the surviving prototype of that responsible for the 1918 pandemic influenza of man. The swine virus appears, however, to be no longer pathogenic for man, and proof of the theory must await a future pandemic outbreak of the disease. There is no way of telling, as yet, whether human influenza is a pure virus infection or whether, like the swine disease, both the virus and a bacterium are essential to its causation.

A NEW APPARATUS FOR TRANSFUSION AND INTRAVENOUS MEDICATION

ONE of the advances in surgical adjuncts is an apparatus of French manufacture for blood transfusion, slow injection of glucose and other intravenous medication, withdrawal of fluid from a cavity, oxygen injection and prolonged anesthesia. The apparatus is very light, is contained in a wooden box $14'' \times 7'' \times 8\frac{1}{2}''$, is extremely simple, and can be manipulated by one operator.

In blood transfusion it permits direct connection between the vein of the donor



BLOOD TRANSFUSION APPARATUS

and of the recipient without any intermediary other than a flexible rubber tube and hypodermic needles. The blood, which flows continuously, is in contact only with the tube, which is absolutely smooth and of uniform calibre, thus reducing to a minimum the risk of coagulation. The apparatus is so constructed that the accidental reflux of blood from the receiver into the vein of the donor is prevented. The mechanical action which assures the flow of the blood takes place outside the tube through which the fluid circulates. It may be employed for paracentesis (with removal of a large quantity of fluid) and then by reversing the movement of the machine, for injection of medication into the body cavity.

The apparatus is air-tight. Sterilization is not necessary, except, of course, for the rubber tubes. Several successive transfusions can be carried out in a minimum space of time, the only necessity being to have on hand a sufficient number of sterile tubes.

An electric motor causes a roller to revolve which, by pressure on rubber tubing contained in the machine, creates a suction behind it and a compression before it, and assures a continuous progress of fluid as long as the motor is in action. At each revolution, when a medium-sized tube is used (there being three sizes), a cubic centimeter of blood is propelled from the donor to the recipient. Every step may be followed by noting the indexes of the manometers, and the quantity of fluid that has passed can be determined at all times.

When there is no electrical current available, for instance, on the battlefield or in remote rural districts, the apparatus may be manipulated with perfect ease by a hand crank.

The manometers are utilized where the output of the fluid can not be noted visually, as in blood transfusions. These instruments immediately register any accidental obstruction or the reduction of the flow of the fluid resulting from the use of a very fine needle—the suction indicator drops or the pressure indicator rises, according to which is impaired. If the proper speed is maintained there should be no stagnation of the blood in the tube, as the fluid is kept constantly in motion.

By connecting the jack supplied with the apparatus to the terminals of a recording machine, it is possible to obtain a graph recording the quantity of a drug injected into a patient (indicated by the number of revolutions of the pump) as well as the reaction of the heart.

The output of the apparatus, functioning as a pump, may be varied at will from 15/100 cc to 300 cc per minute, according to the size of the tube used and the speed of the motor.

This apparatus of L. Henry and Dr. P. Jouvelet was tested for six months, independently, by the military and the naval authorities of France, and has been adopted by the French Army, Navy and Department of the Colonies.

WILLIAM SEAMAN BAINBRIDGE,